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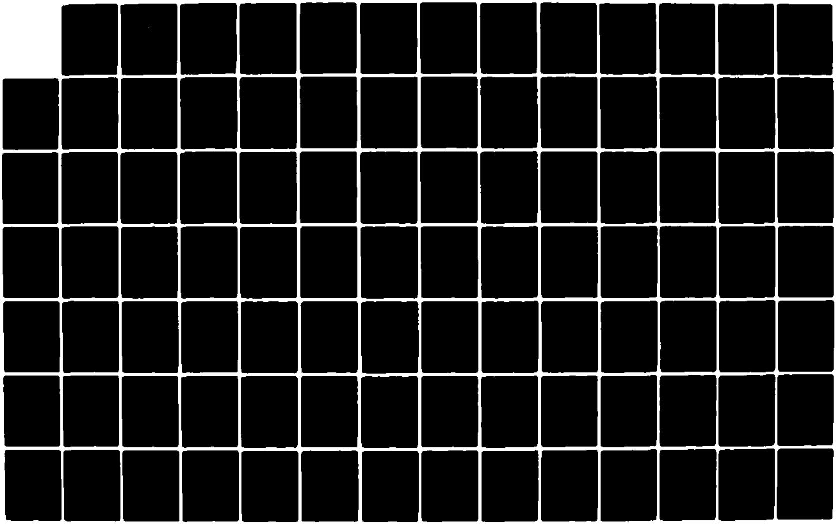

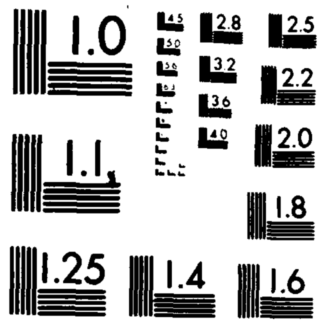

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The report presents practical guides to forecasting water use under four distinct applications providing specific suggestions for approaches to common problems.

FORECASTING MUNICIPAL AND INDUSTRIAL WATER USE:

A HANDBOOK OF METHODS

by

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LIST OF ABBREVIATIONS

gpcd	Gallons per capita per day
gpd	Gallons per day
gped	Gallons per employee per day
gpm	Gallons per minute
HH	Household unit
MFR	Multi-family residence
mgd	Million gallons per day
pphh	Persons per household
SFR	Single family residence
SIC	Standard Industrial Classification
SMSA	Standard Metropolitan Statistical Area

I. HOW TO USE THIS HANDBOOK

Purpose

The U. S. Army Corps of Engineers plans, designs and constructs water resource development projects which typically include water supply as one of a number of purposes. The Corps also prepares water resource management plans for river basins, metropolitan areas, or other subdivisions in response to specific Congressional mandates, or as a consequence of requests for technical assistance from state or local governments. Forecasts of future municipal and industrial water use are central to all of these activities. The timing and scale of projects, and the usefulness and relevancy of water management plans, depend critically on the quality of water use forecasts.

This report is one of a series of documents intended to assist Corps field planners in applying the best and most appropriate techniques to each water use forecasting problem. IWR Contract Report 81-C03, *An Annotated Bibliography on Techniques of Forecasting Demand for Water*, (Dziegielewski, *et al.*, 1981, cited as *Annotated Bibliography*) provides an overview of the literature on this subject. Issued at the same time, IWR Contract Report 81-C05, *An Assessment of Municipal and Industrial Water Use Forecasting Approaches*, (Boland, *et al.*, 1981, cited as *Forecasting Assessment*) contains a critical evaluation of the principal forecasting methods now available. Using the results of that evaluation as a point of departure, this handbook is intended as a practical guide for planners engaged in performing water use forecasts, providing specific suggestions for approaches to common problems.

If there is a lesson to be learned from this handbook it is this: *there is no single method which is suitable for all applications.* Rather, there are a variety of forecasting methods which may be considered, ranging from the most simplistic to complex, data-intensive techniques. In every forecasting situation, the method chosen should make the best use of available data to provide a credible, reliable forecast. This handbook illustrates, by a series of practical examples, the choice and application of forecasting method in each of a range of planning situations. The examples, together with general discussion of common data collection and forecasting problems, are intended to assist the field planner in making informed choices among forecasting methods, in properly applying the chosen method, and in accurately interpreting the results.

Organization

The handbook has two main divisions: Sections I-IV treat a range of general issues; while Sections V-IX provide practical examples of the actual application of methods and approaches discussed. Section I is intended to give the reader a general overview of the handbook, and to indicate the intended use of the information contained. Section II discusses data availability and data collection, and its relevance to the choice of forecasting method.

Section III describes, briefly, available forecasting methods, together with criteria for their selection. This is followed by Section IV, which reviews a number of common forecasting issues and problems.

Sections V through VIII provide descriptions of the actual application of various forecasting methods, ranging from the simplest to one of the most complex (The IWR-MAIN System). In addition, Section IX describes the application of a probabilistic forecasting method to the forecast previously developed in Section VII. References to related literature are given in Section X.

Use

This handbook is organized as a reference work, rather than as a treatise on water use forecasting. It is hoped that field planners will be able to answer specific questions about forecast techniques by referring to specific sections of the handbook, without the need to study all of the material presented. The following paragraphs indicate the proper use of the handbook in the context of some common forecasting problems.

What data must be collected? from which sources?

Section II describes data types and data sources, and offers some general guidelines for determining the proper data collection effort. Four discrete levels of data availability are defined in order to facilitate later discussion. The planner should note which defined level or levels most closely resemble the forecasting problem at hand.

What forecasting method or methods should be used? what are the strengths and weaknesses of alternative methods?

Forecasting methods are described in general terms in Section III, together with criteria for choosing the appropriate method in each application. In some cases, the level of available data will restrict the effective choice to a few methods. Where more data are available, the choice of methods is wider.

How is the study area defined?
What about study areas which contain more than one water supply system?
How is water conservation incorporated into the forecast?

Must the forecast be disaggregated by user sector?
How about with- vs. without-project conditions?

These and other issues arise in most water use forecasting applications. They are discussed in general terms in Section IV. In addition, the examples given in Section V through IX indicate how these issues were handled in the context of specific applications.

How should the selected forecast method be applied?
How much documentation is typically required?
How should forecast results be interpreted?

Sections V through VIII consist of practical examples of water use forecasts associated with each of the four levels of data availability. Each section describes the application of the selected method, and presents and discusses the results. Also, Section IX illustrates a probabilistic technique for dealing with certain assumptions. While this technique can be used in conjunction with most forecast methods, it was applied here to the results of the forecast performed with level 3 data (Section VII).

It can be seen that most users of this handbook will need to become generally familiar with the contents of Sections I through IV. The material in Sections V through IX can be referred to as needed.

II. DATA

Data Sources

DATA TYPES

Three general types of data may be of interest:

1. Past levels of water use (aggregate and/or disaggregate);
2. Past levels of potential explanatory variables; and/or
3. Projected future levels of potential explanatory variables (existing projections by other agencies).

Water use forecasts always require data for one or more potential explanatory variables, and usually require data for water use itself. An explanatory variable is one which has been observed to explain, in whole or in part, past variations in water use. It can be expected, therefore to assist in explaining variations in future water use. The most frequently used explanatory variable is service area population, although many other demographic, socio-economic, geographic, climatic, and technologic variables can be considered. One of the simplest available forecasting approaches (the per-capita method) requires knowledge of past aggregate water use (item no. 1), past population levels (item no. 2), and expected future population levels (item no. 3). More advanced methods may use detailed disaggregations of past water use and historic values for as many as several hundred explanatory variables, as well as projections for some of these.

Table II-1 lists factors which are known to affect municipal and industrial water use. These factors identify or suggest many of the variables which may be considered. As these factors determine water use at the individual user level, variables must also be provided which indicate the number of users (population, number of households, number of connections, number of industrial users, etc.).

Water use forecasts may be made on the basis of time-series or cross-sectional analysis. Time-series analysis examines historic variations in water use, in response to variations in the levels of explanatory variables, within the service area under study. Cross-sectional analysis, on the other hand, focuses on variations in water use among a number of locations (cities, urban areas, etc.) in response to variations in the levels of explanatory variables for those same locations. Cross-sectional data usually pertain to a single time period, although time-series and cross-sectional data may be used together. Each method has advantages and disadvantages, as discussed in Section IV. The method chosen determines the data to be collected

Table II-1. Factors Which Influence Municipal and Industrial Water Use

Municipal Water Use		
A. Inter-Regional Factors	B. Municipal or Intra-Regional	C. Household Variables
i) Physical conditions: precipitation, temperature, moisture deficit. ii) Financial, legal and political constraints. iii) Cultural milieu.	i) Quality of service: water quality, supply dependability, distribution pressure. ii) Policy variables: regulation/prohibition on day, time, amount and purpose of water use; water rate structure, metering, minimum bill, frequency of billing, amount of water allowed with minimum bill, width and level of price blocks; consumer education; inspection and repair of faulty plumbing; waste reduction (mains leakage control); allocation of water of different quality to different uses.	Density of housing Household size Income level and related economic variables such as ownership, frequency of use, efficiency of water using equipment, size of lot, area in lawns or shrubs, assessed sales value of residence, type of housing. Legal, cultural constraints or incentives. Consumer preferences, habits and tastes. Connection to public sewer

Industrial Water Use		
Employment	Water recirculation rates	Age of firm
Employee productivity	Input of raw materials	Price of water (metered or bought)

SOURCES

There are two major sources of data available to the forecaster. First, data may be obtained from state or regional agencies, including water resources boards, employment security agencies, industrial development agencies, departments of community and economic affairs, and planning agencies. Water resources agencies may be able to give a good assessment of planning for water resources as well as an inventory of the extent and nature of water resources data within the region. Listings of state and regional agencies may be found in most public libraries. Second, water utilities and local planning agencies within the study area can usually indicate the availability of local data. Common sources for selected variables are shown on Table II-2.

The difficulty of obtaining data depends to a large extent on the level of water use disaggregation chosen. The finer the level of disaggregation (in terms of the size of the service area and the extent of sectoral breakdown), the more difficult it is to obtain, for example, detailed demographic information for intercensal years. Often data are only available for the state or SMSA, which may be much different from the study area. Generally, the smaller the study area, the more reliance must be placed on data from local agencies. However, state or regional planning agencies should always be contacted as they may have undertaken studies in various regions and will perhaps have some detailed information for smaller areas.

Disaggregation of data remains a problem if the relevant information is only available from federal sources. For example, the most disaggregate OBERS population projections are for SMSA's. If these are the only population projections available and the study area is smaller than the SMSA, judgments must be made as to what percentage of growth can be attributed to the study area. Alternatively, it may be preferable to extrapolate the growth rate on the basis of historic data for the study area.

Data Collection Effort

The effort required to secure data varies widely from variable to variable, and from forecasting application to forecasting application. Some data may be readily available in the required form, either in Corps offices (data already collected for an Existing Conditions Report, planning study, etc.) or in the offices of the water utility or a state or local agency. Data collection effort, in these cases, may consist of a telephone call, an exchange of correspondence, or an office visit. In other cases, data collection may require strenuous and time-consuming efforts, such as manual analysis of water billing records, field survey of users, continual referral from agency to agency in search of data, etc.

Perhaps the single most important decision in the development of a forecast is to determine how much data to collect. This decision influences the

Table II-2. Data Sources for Commonly Used Variables

Historic Data

1. Water use data (municipal and industrial)

   Water utility

2. Population data

   State, regional, or local planning agency
   Water utility
   Economic development agency
   City or regional planning agency
   U. S. Census of Population

3. Number of households or dwelling units: other demographic variables

   State, regional, or local planning agency
   U.S. Census of Population, Housing

4. Number of connections

   Water utility

5. Climatic data

   National Weather Service, NOAA, U.S. Dept. of Commerce
   Dept. of Meteorology or Climatology, State University
   Water utility

6. Water and wastewater rate structure

   Water utility

7. Other economic variables

   State, regional, or local planning agency
   U.S. Census of Population, Housing, Business, Manufactures
   Real property assessment agency

8. Policy variables

   State or local governments
   Water utility

Table II-2. (cont.) Data Sources for Commonly Used Variables

Historic Data

9. Manufacturing employment, output, processes

    Local or regional economic development agency
    State employment agency
    U.S. Census of Manufactures
    U.S. Bureau of Labor Statistics
    Individual firms

Projected Data

10. Population, household size, number of households, etc.

    State, regional, or local planning agency
    Economic development agency
    OBERS projections

11. Economic variables

    State, regional, or local planning agency
    OBERS projections

12. Manufacturing employment

    State, regional, or local agency
    Economic development agency
    OBERS projections
    Individual firms

choice of forecasting method and has a major impact on the quality and credibility of the resulting forecast. The more accurate and complete the data used, the more reliable and useful the resulting forecast, and the more efficient and productive the plans and projects that result from the forecast. In every case, the data collection effort must be designed to balance the cost of data collection against the value of improved forecast quality.

Many forecast methods require information on historic water use disaggretated by user sector (residential, commercial, etc.). Disaggregate forecasts provide more complete information to the planning process, facilitate the consideration of water conservation, and comply with the requirements of federal water resource planning procedures. Yet few water utilities are able to provide disaggregate water use data. Sometimes the data may be obtained by analysis of billing records; in other cases, there may be no immediate means of classifying customer accounts by user sector. Still, the data can be obtained. With the cooperation of the water utility, meter readers can be used to classify accounts, so that billing records can later be analyzed. The task may require several meter reading cycles to complete, and should be undertaken wherever justified by the resulting improvement in the quality of the resulting forecast. It is the responsibility of the planner to determine the appropriate data collection effort in each planning situation.

Data Levels

As discussed in Section III, forecasting methods are chosen according to the forecast application, the characteristics of the study area, and the type and quality of data which are available given appropriate data collection effort. In order to simplify discussion of the relationship between data availability and forecasting method, four discrete levels of data availability are defined on Table II-3. These levels are broadly defined, and actual data sets may not exactly conform to any of them. Still, the defined levels are useful as benchmarks to indicate relative amounts of data, so that appropriate forecasting methods can be suggested. Where an application involves data exceeding, in some respects, one of the defined levels, but not fully corresponding to the next higher level, techniques from several forecasting methods may be combined to yield a forecast which makes use of all available data.

Table II-3. Levels of Data Availability

LEVEL 1 —	Water Use Data:	Readily available aggregate production and customer data
	Demographic Data:	Aggregate data available from public records, such as Census reports
	Other Data:	Qualitative descriptions of service area characteristics and trends
LEVEL 2 —	Water Use Data:	As in Level 1, except data on industrial water use separately available
	Demographic Data:	As in Level 1
	Other Data:	As in Level 1, plus climatic, demographic, economic and other aggregate data available from public records
LEVEL 3 —	Water Use Data:	Water use and customer data disaggregated by user sector
	Demographic Data:	As in Level 1, plus additional data on family sizes, housing characteristics, etc.
	Other Data:	As in Level 2
LEVEL 4 —	Water Use Data:	As in Level 3
	Demographic Data:	Comprehensive data are available regarding household numbers, sizes, compositions, including forecasts of key variables
	Other Data:	Comprehensive socio-economic data are available, including employment characteristics and forecasts, water prices, family incomes, home values, commercial activities, etc.

III. FORECASTING METHODS

Overview

A complete review of water use forecasting practice would reveal a very large number of individual methods and techniques. Many of these are described in the literature (see *Annotated Bibliography*) in at least general terms. In order to analyze and compare methods, the *Forecasting Assessment* groups them into categories, where each category contains a range of specific techniques having similar characteristics.

Some categories, such as simple prediction (pure judgmental forecasting), collective judgement (e.g., Delphi techniques), and simple time extrapolation (using no explanatory variables other than time) can be omitted as they have little or no acceptance in forecasting water use. Six categories are defined:

1. Per capita methods
2. Per connection methods
3. Unit use coefficient methods
4. Multivariate requirements model methods
5. Demand model methods
6. Contingency tree methods.

The first three categories include only single coefficient methods: they each employ a single explanatory variable. The fourth and fifth categories contain multiple coefficient methods, using more than one explanatory variable. The sixth category, contingency tree methods, represents a single type of probabilistic approach. Other approaches would be possible, but are not yet found in practice. The characteristics of these six categories are summarized on Table III-1.

Of the single coefficient methods, the per capita approach is, by far, the most widely used. As shown in the *Forecasting Assessment*, however, it has serious shortcomings in most forecasting applications. By limiting the number of explanatory variables to one – population – the per capita method omits many factors known to affect water use: housing type, household size, climate, levels of commercial activity, income, price, etc. The U.S. Water Resources Council *Principles and Guidelines* (1983) state that these additional factors should be included, and that forecasts should be prepared on a sectorally disaggregated basis (separately for each major user sector). The per capita method does not lend itself to either goal.

Because of the omission of most explanatory variables and the necessarily aggregate nature of the per capita method, it is difficult to determine the effectiveness of individual water conservation measures, hindering the full evaluation of water conservation as an alternative to supply. Accordingly, the per capita method is not suitable for most project planning applications, although it may suffice for preliminary or reconnaissance studies which later lead to project identification and planning. On the other hand, this method is simple, requires little data, and the data are easily obtained.

Table III-1. Comparison of Forecasting Approaches

	Single Coefficient Methods			Multiple Coefficient Methods		Probabilistic Methods
	Per Capita	Per Connection	Unit Use Coefficient	Requirements Model	Demand Model	Contingency Tree
Facilitates forecasts consistent with Principles & Guidelines	no	no	when used in disaggregate forecasts	when used in disaggregate forecasts	when used in disaggregate forecasts	yes
Facilitates evaluation of water conservation measures	no	no	"	"	"	yes
Suitable for preliminary or reconnaissance studies	yes	yes	yes	no, too complex	no, too complex	no, too complex
Suitable for project planning applications	no	no	when used in disaggregate forecasts	when used in disaggregate forecasts	when used in disaggregate forecasts	yes
Quantity of data needed	very little	very little	moderate	moderate to large	moderate to large	depends upon application
Difficulty of obtaining needed data	low	low	low to moderate	moderate to high	moderate to high	depends upon application

Source: Adapted from Table III-2, p. III-35, in the *Forecasting Assessment*.

Another type of single coefficient approach replaces the population variable with number of connections (customers). The advantage of per connection methods is that historical data on number of connections to a water supply system is more readily available and more accurate than data on past population, which must be allocated to the service area and interpolated between census years. Number of connections is well correlated with number of household units, which is, in turn, better correlated with water use than is total population. Aside from these factors, which refer primarily to data availability and reliability, the per connection method retains all of the advantages and disadvantages of the per capita method.

Other methods based on a single explanatory variable (other than population or number of connections) are collectively named unit use coefficient methods. These methods may be applied to aggregate water use (as a function of number of households, for example) or to sectoral water use within the framework of a disaggregate forecast. In the latter case, commercial water use may be forecast as a function of number of households, and industrial water use as a function of number of industrial employees, for example. When used in a disaggregate forecast, the unit use coefficient methods may be consistent with the *Principles and Guidelines* (provided significant explanatory variables are not omitted) and permit evaluation of water conservation measures. These methods may be used in all types of studies and require only moderate amounts of data, usually available with low to moderate difficulty.

Methods which incorporate more than one explanatory variable fall into one of two categories: those employing requirements models and those using demand models. Requirements models include variables observed to be significantly correlated with water use, not necessarily including price of water, and household or per capita income. Demand models, on the other hand, are based on economic reasoning, and include only variables which are (1) expected to be causally related to water use and (2) found to be significantly correlated with water use. Demand models include price and income, as well as other variables. The number and nature of explanatory variables actually used in these models may vary greatly from one application to another, according to data availability, required accuracy, local conditions, etc.

Multiple coefficient methods, when employed in disaggregate forecasts, meet the requirements of the *Principles and Guidelines* and permit full evaluation of water conservation measure effectiveness. They are, in general, too complex for preliminary or reconnaissance studies, but are well suited to most other planning applications. Data requirements may be considerable, depending upon the number of explanatory variables used, and some types of data may be comparatively difficult to collect. Data collection efforts, of course, must be balanced against potential improvements in the reliability of the forecast.

Contingency tree methods, the only type of probabilistic approach examined here, provide a means for considering uncertain factors in a water use forecast. Ordinarily the contingency tree approach requires that a base forecast be prepared by one of the methods discussed above. The base forecast is then modified to reflect the effect of all possible combinations of the uncertain factors, one combination at a time, and the joint probability of each of the combinations is associated with the forecast water use expected to result from that combination. The characteristics of this method are, in general, the same as the characteristics of the forecast method used to develop the base forecast, except that additional data collection requirements may be imposed. Also, probabilistic methods are likely to be too complex for preliminary or reconnaissance planning efforts.

Selection Criteria

DATA AVAILABILITY

The forecasting methods described in this section have widely different data requirements. The quantity and type of data available, therefore, determine which forecasting methods can be considered for use. Data availability, in turn, is a function of local conditions and data collection effort. In principle, virtually any kind of data can be obtained with sufficient effort. As noted in Section II, the data collection effort expended in each application should represent a balancing of the cost of collection and the benefits derived from better and more reliable forecasts. One of the sources of those benefits is the ability to use more advanced forecasting methods.

Table III-2 shows, in general form, the relationship between data availability and possible forecasting method. For data levels 2 through 4, the forecasting methods shown for lower levels can also be applied, although there would seem little reason for doing so. When sufficient data are available, more advanced methods should yield results at least as satisfactory as simpler methods; frequently better results can be obtained. Where actual data availability exceeds one defined level, but falls short of corresponding to the next higher level, consideration should be given to methods listed for both levels: methods listed for the higher level, or variants of those methods, may be feasible.

STUDY AREA CHARACTERISTICS

The characteristics of a study area include such aspects as the makeup of housing stock (% apartments, % single family, etc.), major institutional water users, past trends in household size, distribution of family income, expected future changes in residential lot sizes, etc. Within the limits imposed by data availability, these characteristics can affect the choice of forecasting method, and the way in which a particular method is implemented.

Table III-2. Forecasting Methods and Data Requirements

Data Availability*	Applicable Forecasting Methods**
Level 1	Per capita methods Per connection methods Unit use coefficient methods (aggregate forecasts only)
Level 2	Unit use coefficient methods (limited disaggregation) Multivariate requirements methods (limited variable list, limited disaggregation)
Level 3	Multivariate requirements methods (limited variable list)
Level 4	Multivariate requirements methods Demand model methods

*Data levels are defined on Table II-3.

**Contingency tree methods can be applied at any level of data availability, although the scope of application is restricted for levels 1 and 2.

In principle, variations in water use can be explained by a number of alternative sets of explanatory variables, and many individual variables can be replaced by any of a number of surrogate or alternative specifications. Based on historic correlations, residential water use may be described as a function of population and number of households, as a function of household size and number of connections, or as a function of number of households and per capita income. While each pair of variables may be as satisfactory as any other pair in explaining water use, they may not provide equally desirable forecasting models. For example, if a credible population forecast exists, the first combination of variables would allow it to be used in the forecasts. But if a recent study shows clear trends in household size which may be expected to continue, the second combination may be more helpful. On the other hand, if per capita income has changed slowly in the past, but is expected to change dramatically in the near future, the third combination of variables may allow that projection to be incorporated into the water use forecast.

Where definite expectations exist regarding future trends in certain variables, the forecasting method chosen should include those variables explicitly, so that expected trends can be reflected in the water use forecast. Also, expected future trends may affect the level of disaggregation chosen, so that trends affecting only one user sector may be addressed. As in the case of data availability, the forecast method should be chosen to make the best possible use of available information.

FORECAST APPLICATION

The final consideration in selecting a forecast method is the application or final use of the forecast results themselves. If the application requires only a forecast of average annual aggregate water use, most methods and techniques can be used, subject to data availability and conformance with study area characteristics. If the forecast is to be used in the design of treatment and conveyance works, however, methods that can produce reliable estimates of maximum day water use may be required. Design of a surface water impoundment may, depending on project size and purpose, require forecasts of seasonal water use and maximum month use, as well as average annual water use. In other cases, alternative forecasts may be required to show the effect of various levels of economic development on water use. The forecast method chosen must include the appropriate economic measures as explanatory variables, so that the effect of different economic conditions can be seen as different levels of water use. Forecast methods, then, in addition to making the best use of available data and information, must provide the necessary water use information to the planning process.

IV. OTHER ISSUES

This section reviews a number of issues common to many water use forecasts. Its purpose is to provide a general background and guidance for dealing with these issues. Specific examples of some problems discussed here also appear in Sections V through IX.

Study Area Definition

The first step in every water use forecast is a careful definition of the geographic area to which the forecast applies. This step is required even when the forecast is a part of a larger water resource planning activity, as the study area adopted for the overall planning study may not be appropriate to the water use forecast. Every forecasting effort must begin, therefore, with the definition, or at least the reexamination, of the study area.

In general, a study area is the service area of one or more water utilities. Deviations from this definition may be required as a result of the following considerations:

1. A water utility may anticipate expansion of its service area during the forecast period. In areas with positive economic growth, this is almost always the case. The study area must be expanded, therefore, to coincide with the largest service area expected during the planning period.
2. A portion of an existing water utility service area may be without public water service at the present time, and unlikely to receive it during the planning period. This situation often occurs when service areas are defined as coterminus with political jurisdictions, and when those jurisdictions include large tracts of rural or undeveloped land. It may be helpful, in these cases, to reduce the study area to correspond to that area likely to be served by the public system at some time during the planning period.
3. The planning context of the forecast activity may require inclusion of self-supplied industrial users of water (not connected to the public supply systems) located outside the utility service area. The study area must then be expanded to include these self-supplied users. Also, certain industrial users may be located outside the utility service area but still receive public water supply service, by means of private pipelines. Again, the study area must be defined to include these users.
4. Where service area boundaries do not coincide with political subdivision boundaries, problems will arise in obtaining demographic and socio-economic data which correspond to water using activities. Two solutions are possible: (1) disaggregation of the demographic and socio-economic data to obtain data specific to the service area, or (2) expansion of the study area to correspond with the political jurisdiction for which data are available. The first solution results in lower quality explanatory variable data, because of

necessarily arbitrary disaggregation techniques (note that characteristics of the portion of a political subdivision which lies within a public water supply service area are likely to be quite different from those of the area without public water service). The second solution results in lower quality water use data, since it includes self-supplied users outside the utility service area, for whom no actual data are available. In each application, the analyst must determine which approach will cause the least difficulty.

5. It is sometimes helpful to divide a study area into two or more subareas, because of substantially different data availability among the subareas. Each subarea is defined according to criteria similar to those applying to the full study area. Water use forecasts performed under these conditions are known as "multi-jurisdiction forecasts" and are described in the following paragraphs.

Multi-Jurisdiction Forecasts

Some study areas are characterized by substantial geographic variation in the availability of data. Most often this applies to water use data, which may be available in disaggregate form for one part of a study area, and in aggregate form in another (e.g., unmetered) jurisdiction. This may be the result of several independent water utilities, with different management and record-keeping practices, operating within the study area. It also occurs when one water utility sells water at wholesale (through a bulk meter) to another utility, which may serve a small suburb, or even a single housing development.

Multi-jurisdiction problems are treated by defining subareas which correspond to the areas of relatively uniform data availability. Data collection effort can then be determined independently for each subarea, based on the availability of various types of information, and the improvement in forecast quality which additional data can provide. Forecast methods are selected independently for each subarea, and separate subarea forecasts are performed. The separate forecasts can then be combined to form a forecast for the entire study area.

It is important to note that data constraints result in lower quality forecasts only for those subareas where the constraints actually apply. Other subareas are forecast by more advanced methods which fully utilize available data. The tradeoff between data collection effort and forecast quality is performed separately for each subarea.

Where a multi-jurisdiction approach is used for a series of subareas served by interconnected water utilities (e.g., where a large water utility sells water at wholesale to other utilities for distribution), a problem may arise with data on public and unaccounted water use. Since this unmetered sector of water use is conventionally defined as the residual remaining after deducting all metered use from total production, it is not always possible to allocate public and unaccounted use among the interconnected jurisdictions.

The problem can be illustrated by the case of a large water utility serving a smaller one through a single bulk meter. If production meters are accurate, public and unaccounted water use measures all unmetered uses including water withdrawn from fire hydrants, all leakage from the transmission and distribution systems, and all misregistration of user meters. If the bulk meter serving the small utility is also accurate, and if no part of the large utility's transmission or distribution system is dedicated to the exclusive use of the wholesale customer, then observed public and unaccounted use is solely attributable to the large utility. If the bulk meter underregisters actual use, or if a transmission line (with potential leaks) is provided to serve the bulk meter alone, then some part of the public and unaccounted water use is properly attributable to the wholesale customer. The exact amount cannot ordinarily be determined, but may be estimated with accuracy suitable for most purposes provided the causative factors are adequately investigated.

Water Conservation

Water conservation measures must be considered in forecasting water use under three sets of circumstances:

1. Where water conservation measures have been implemented in the study area during the recent past;
2. Where definite commitments have been made to implement water conservation measures within the study area during the planning period; and/or
3. Where water conservation is to be considered as an alternative to water supply measures in meeting projected supply deficits.

The action to be taken in the case of previously implemented conservation measures depends upon the choices of base year and forecast method. If all measures were fully effective prior to the base year, and the forecast method used does not employ water use data from the period before the base year (e.g., does not use time-series analysis of water use data), no explicit consideration of water conservation is required. The effectiveness of the measures should be fully incorporated into the forecast.

On the other hand, where measures were not yet implemented or were not fully effective during the base year, or where time-series analysis is contemplated, adjustments to observed water use data may be required. All water use data must be consistent with respect to conservation implementation: all data must assume no implementation, or the same level of implementation. Normally, it is desirable to adjust observations downward to incorporate the full effectiveness of the measures employed. This provides a basis for forecasting future water use, based on the assumption that the water conservation measures remain in force.

Methods for adjusting water use to account for conservation are found in the conservation *Procedures Manual* (Baumann, *et al.*, (1980)) especially paragraph 4-8. In applying these methods to past water use, references to "unrestricted future water use" should be interpreted as applying to observed water use, and adjusted water use is found by deducting the calculated effectiveness of water conservation (determined according to the procedure) from observed water use.

In the second case, where commitments have been made to implement conservation measures after the base year, water use forecasts are first made without the conservation measures, then adjusted for the affected years. As above, adjustments are made according to the *Procedures Manual*. References to "unrestricted future water use" apply to unadjusted forecast water use; adjusted forecast water use is found by subtracting the calculated effectiveness of water conservation from the unadjusted forecast.

Where water conservation is to be considered as an alternative to water supply augmentation, project planning includes the development of a water conservation plan. The *Procedures Manual* gives step-by-step instructions for the preparation of this plan, and for its integration into the water supply plan. The *Procedures Manual* also describes, as noted above, a method for determining the effectiveness of water conservation measures in reducing water use. These adjustments are applied to the "without-project" forecast which is already modified for conditions described for cases 1 and 2, above if necessary. The result (after consideration of other project-induced effects) is the "with-project forecast, described below.

With- vs. Without-Project Conditions

When water use forecasts are prepared for purposes of project evaluation, consideration must be given to the effect of the project on future patterns and levels of water use. In general, forecasts are required for future water use in the absence of the project (the "without-project" condition) as well as for future water use in the presence of the project (the "with-project" condition). In the case of the "without-project" condition, future water needs are met by existing facilities, locally-planned additions or replacements, locally-implemented conservation measures, etc. The "with-project" condition differs in the substitution of a federally-planned facility or program for all or a portion of the locally-planned alternatives.

A number of determinants of water demand are potentially affected by the implementation of a federally-planned project or program. The most likely candidate is the future price at which water will be sold to users. Where the federal plan is a net contributor to National Economic Development, it is likely to result in lower real prices than would otherwise have been the case. Implementation of federal water supply plans may also affect land use (development of large impoundments in or adjacent to the study area, for example), economic development patterns (as a result of other purposes of a multi-purpose project), or housing patterns (because of different patterns of flood plain development, for example). All of these changes translate into altered values for projected future explanatory variables, and, therefore, revised levels of forecast water use.

The extent to which project-induced effects can be reflected in a water use forecast depends upon the forecast method chosen. Simple techniques, such as the per capita method, are insensitive to changes in price, in housing patterns, or in economic development patterns. Subjective adjustment may be made to the per capita use coefficient to reflect presumed changes, but such ad hoc changes are likely to be unreliable and to lack credibility. More advanced forecasting methods, incorporating a number of explanatory variables, permit better identification of possible project-induced effects. Methods incorporating demand models permit consideration of changes in price, probably the most frequent and significant impact of federally-planned projects on future water use.

Where the federally-planned project includes water conservation measures as one of the means of meeting future water needs, the effectiveness of the planned conservation measures must be determined, as described in the *Procedures Manual*. The with-project water use forecast is obtained by deducting the calculated effectiveness of the conservation measures from a forecast which includes any other project-induced effects.

Alternative Futures

Forecasts are described as conditional predictions of future events. A water use forecast is conditional upon the accuracy of numerous assumptions and projections of explanatory variables. Each assumption and explanatory variable projection represents a condition considered likely to occur in the future. In some cases, a number of alternative assumptions or alternative projections may all be considered likely, with no obvious "most likely" choice.

In these cases, it may be desirable to prepare a number of alternative water use forecasts, each forecast corresponding to one alternative set of assumptions and projections. In this way, the sensitivity of future water use to the range of assumptions can be determined, and something of the level of uncertainty inherent in the forecast is revealed. The practice of preparing a number of forecasts, based on various sets of assumptions, is called the method of alternative futures. It is most useful where significant uncertainty exists concerning key assumptions or projections of explanatory variables, where the reliability of future water supply is an important concern, or where a range of policy options is to be investigated. An extension of the method of alternative futures, which incorporates explicit probability measures, is the contingency tree technique described in Section IX.

Forecasting methods differ widely in their ability to support investigations of alternative futures. The simplest methods, especially those utilizing a single coefficient (per capita method, per connection method, unit use coefficient methods), do not permit systematic variation of assumptions except to the extent that those assumptions affect the single explanatory variable (population, number of connections, etc.). Multiple coefficient methods are better in this respect, and the sectorally disaggregated methods provide the most flexibility in adopting alternative sets of assumptions. In general, the fewer the explanatory variables, the less scope there is for considering alternatives and the more the analyst is required to accept a single set of implicit assumptions for all forecasts.

Sectoral Disaggregation

Water use forecasts can be disaggregated in almost any way in which water use itself can be broken down. The most common disaggregations are according to user sector (residential, commercial, industrial, etc.), time-of-year (winter vs. summer, seasonal vs. nonseasonal, etc.) and geographic subarea. Geographic disaggregation is simply an extension of multi-jurisdiction forecasting, described above. Sectoral disaggregation can range from a two-sector model (usually municipal and industrial sectors) to very detailed divisions within the traditional sectors (such as the 280+ sector IWR-MAIN model).

The purpose of disaggregation is to allow each individual sector of water use to be described and forecast in terms of explanatory variables which relate specifically to that sector, or whose relationship with that sector differsfrom those applying to other sectors. Thus industrial water use can be described in terms of industrial output while residential water use is a function of residential population; seasonal water use may have one type of relationship to price while nonseasonal water use can be allowed to have a quite different relationship to the same variable. Where sufficient data of adequate quality can be made available, disaggregate models produce much more accurate and useful forecasts than do simpler, aggregate methods.

The *Principles and Guidelines* (1983) state the need for disaggregate forecasts in project planning. In addition, the *Procedures Manual* notes that sectorally and seasonally disaggregate forecasts are required for adequate evaluation of water conservation measures. In most forecasting applications, every effort should be made to develop disaggregate forecasts, with the level of disaggregation adjusted to suit data availability, study area characteristics, and forecast requirements.

The major obstacle to wider use of disaggregate forecasts is the availability of sectorally disaggregate water use data for base years, or for historic periods. While some water utilities routinely obtain such data, most do not. Where all customers are metered and customer records are coded to indicate the proper sector for each account, disaggregate data can be extracted from existing billing records. If billing is automated and records are machine readable the data may be available comparatively quickly at low cost. Manual extraction of data is time-consuming, but may still be desirable depending on the size of the utility.

In other cases there will be no indication of the proper sector classification on customer records, or the sectors used may be undesirable for forecasting purposes. In this case, all accounts must be coded (or recoded) before the data extraction can begin. Coding is easily accomplished by providing meter readers with a list and explanation of sectors, and requiring them to code each account as the meter is read. Allowing for misses, errors, and other problems, several meter reading cycles may be required to cover all accounts. Labor costs are small and disaggregate data can still be obtained, in most cases, within one year.

Where time, budget, or data extraction methods do not permit complete analysis of all billing records, a sampling procedure may be used to estimate water use in each sector. This approach is described in the following paragraphs.

Sampling Water Use Data

Water use data are frequently derived from the billing records of a water utility, especially when disaggregate use data are required. While it is preferable to analyze all billing records for the time period of interest, there are situations where the records are so numerous, or kept in a form which makes complete analysis infeasible. In these cases it may be possible to obtain adequate estimates from limited samples of the billing records, provided the samples are drawn according to valid statistical procedures.

A sample should provide an acceptably accurate estimate of several statistics (mean, variance, etc.) of the population of records from which it is drawn. If the sample is designed properly, values calculated from it ("estimators") become more reliable as sample size increases. However, as sample size becomes larger, and consequently more reliable, the costs of obtaining and analyzing the data grow as well. The objective in designing a sample, therefore, is to determine the smallest size consistent with acceptable accuracy.

Reliability can be defined as the probability that the sample mean, $\bar{X}$, differs from the true mean of the population of data by no more than a tolerable error, e:

$$\text{Reliability} = P[(\mu - e) \leq \bar{X} \leq (\mu + e)] \qquad \text{(IV-1)}$$

Where: $P[\ ]$ = probability that condition in brackets is satisfied
μ = mean of total population of data (all records)
$\bar{X}$ = mean of sample (sampled records)
e = tolerable error in estimating mean of population.

Thus, two factors must be chosen in order to specify the quality of the sample: the tolerable error (e) and the acceptable probability of not exceeding that error (reliability). If the probability distribution is normal, or can be assumed near normal, useful relationships between tolerable error and acceptable reliability can be derived. While distributions of individual water use are typically positively skewed, they are considered sufficiently close to normality for the following development to be applicable.

If the terms in expression IV-1 are rearranged and divided by the standard deviation of the sample means, reliability may be expressed as:

$$\text{Reliability} = P[\frac{-e}{\sigma_{\bar{x}}} \leq \frac{\bar{X}-\mu}{\sigma_{\bar{x}}} \leq \frac{e}{\sigma_{\bar{x}}}] \qquad \text{(IV-2)}$$

Where: $\sigma_{\bar{x}}$ = standard deviation of sample means

$\frac{\bar{X}-\mu}{\sigma_{\bar{x}}}$ = standard normal statistic, Z

Thus,

$$\text{Reliability} = P[\frac{-e}{\sigma_{\bar{x}}} \leq Z \leq \frac{e}{\sigma_{\bar{x}}}] \qquad \text{(IV-3)}$$

Further manipulation, based on the characteristics of normal distributions, yields:

$$e = Z' * \sigma_{\bar{x}} \qquad \text{(IV-4)}$$

Where: Z' = value of the Z-statistic for the desired level of reliability (obtained from standard statistical tables)

This relationship may be applied to two types of sampling processes:

1. Samples are drawn randomly either with replacement (records are drawn randomly one at a time, with the selected record placed back in the population before the next draw) or from a very large population; or
2. Samples are drawn randomly without replacement from populations which are less than very large.

In the first case,

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} \qquad \text{(IV-5)}$$

Where: σ = standard deviation of the population
n = number of records in the sample

Substituting equation IV-5 into IV-4,

$$e = Z' \frac{\sigma}{\sqrt{n}} \qquad \text{(IV-6)}$$

Solving for n,

$$n = \frac{Z'^2 \sigma^2}{e^2} \qquad \text{(IV-7)}$$

This expression gives the proper sample size based on the desired reliability (which yields the value of Z'), the maximum tolerable error (e), and the standard deviation of the population. The latter value must be estimated, most easily by drawing an arbitrary sample and using the sample standard deviation as the estimator of the population value. The calculation should then be rechecked as the sample size is expanded, so that the final value of n is as efficient as possible.

For the second sampling design, where the data set is smaller and/or replacement is not practiced,

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} \left[\frac{N-n}{N-1}\right]^{0.5} \qquad \text{(IV-8)}$$

Where: N = number of records in the population
Substituting into IV-4, and solving for n:

$$n = \frac{N\ Z'^2 \sigma^2}{(N-1)e^2 + Z'^2\sigma^2} \qquad \text{(IV-9)}$$

Once again, sample size depends upon the desired reliability, the maximum tolerable error, and the population standard deviation. The population size, N, is also included in this formulation. As before, population standard deviation must be estimated from sample data.

Time-Series vs. Cross-Sectional Analysis

Whatever forecasting method is used, the basic tool is a model or models which can adequately explain water use under both current and future conditions. Models can be adopted from other studies or from the literature, or they can be developed from data collected as part of the forecasting effort. More frequently, model forms are drawn from other studies, and specific coefficients are estimated from data collected for the purpose as part of the forecasting effort.

Water use models may be estimated from either time-series or cross-sectional data. Time-series data consist of observations of water use and explanatory variables made over a number of years at the same location (usually the study area). Cross-sectional data are simultaneous observations of water use and explanatory variables at a number of locations during a single time period. Occasionally time-series and cross-sectional data may be used together, but they are more often treated as alternatives.

Time-series data are, in some respects, superior to cross-sectional data for developing forecasting models. By analyzing time-series data, trends in water use over time can be identified and hypotheses developed regarding continuation of these trends into the future. When using a cross-sectional model for forecasting, the assumption must be made that the functional relationship existing among the variables at one point in time will continue into the future. This tends to limit applicability of these models to situations in which underlying relationships have not significantly changed over time.

On the other hand, cross-sectional data usually exhibit much greater variance than do time-series data, permitting more statistically reliable estimates of model coefficients. For example, if the real price of water has varied only about 20 percent during the period for which data are available, expected future changes of 100 percent or more may be difficult to reflect reliably in forecasts. Cross-sectional data may be collected for communities with prices which differ by more than 100 percent from the study area, giving a model which is more likely to produce useful forecasts. Also, some explanatory variables, such as residential lot size, may not have changed at all during the historic period, providing no information as to how water use will respond to expected future changes. Again, cross-sectional analysis can be based on data containing the necessary variation, permitting coefficients to be estimated.

Time-series data, therefore, are generally preferable provided that the historic period exhibits sufficient variation in all of the variables of interest. Where this is in doubt, it may be necessary to collect cross-sectional data from areas chosen to provide the necessary range of conditions. In all other respects, areas selected for a cross-sectional sample should be as similar as possible to the study area.

V. EXAMPLE A — LEVEL 1 DATA

Background and Approach

STUDY AREA

The study area centers on a small city in the mid-Atlantic region with a population of approximately 10,000. The area, relatively removed from major population centers, is located in a mountainous region with a cold temperate climate. A single municipally-owned water utility serves the area including the city and surrounding minor civil divisions.

The housing stock of the city is characterized by a somewhat higher fraction of multifamily units than is typical for other cities of this size. This has resulted from the presence of a state college in the city, leading to the conversion of many single family homes in older sections to provide student living quarters. Land use within the city is primarily medium density residential. Outside the city, land use is mostly residential, developed at low density.

The city has no significant industrial base; industrial employment opportunities occur mostly in neighboring regions, outside the study area. The city was at one time a coal mining center, but this activity suffered a major decline in the 1950's. Coal production is on the rise now, but it is not anticipated to have a significant effect on employment opportunities, due to the high degree of mechanization in the industry. The only viable economic bases are in commercial and service activity, closely tied to the local college.

The college experienced significant growth in student enrollment in the early seventies. In recent years the student population has stabilized, with lack of funding for additional dormitory accommodation being considered one of the binding constraints on growth. Future growth of the college will be determined by state education policies. No significant short-term growth in enrollment is anticipated at this time. The city is increasing its efforts to attract industrial activity and as part of this objective an industrial park has been built which is expected to result in some growth in industrial employment. However, any increase in industrial activity is not expected to affect local population before 1990. New industries are not likely to be significant water users.

FORECAST REQUIREMENTS

A forecast of water use for the Example A study area is required for the period through 2030. The base year is chosen as 1980, due to availability of U.S. Census of Population data. The water use forecast described here is part of a preliminary survey of water supply capability for the area, undertaken by the Corps at the request of the state government. Average day water use is required for the period through the year 2030, at ten-year intervals. No sectoral disaggregation is required, and no consideration of water conservation measures is anticipated as a part of the preliminary survey. The forecast is to cover the total service area of the water utility, including areas served via wholesale transactions with smaller utilities and developers, area to be added to the service area during the planning period, and possible future growth by the state college.

CHOICE OF FORECASTING METHOD

Based on the forecast requirements and on a preliminary assessment of data availability, a single coefficient method is judged most appropriate to this forecast. Further review of data availability led to selection of the per connection method (see Section III), where the per connection use coefficient is determined by time-series analysis (see Section IV). Local government agencies have limited information on the population of the service area during the base year, as well as during previous years, although the base year population can be approximated from Census data. Estimates of previous year population have been performed but are complicated by the lack of information on historic boundaries for the service area. There are, however, good records of the number of connections served directly, and some information on a major wholesale customer, although wholesale data are incomplete.

It is important to emphasize that the choice of the per connection method is dictated by the need to make the best use of available data; this approach involves the least amount of data manipulation and a minimum of assumptions concerning population and study area boundaries. It is also true, however, that number of connections is sometimes a better explanatory variable for historic water use than service area population.

Data Collection

POPULATION AND CONNECTION DATA

Historic Connection Data

City water utility records document the number of direct connections to the system at yearly intervals during the period 1970-1981. Direct connections include a single connection for the state college, and from 2 to 13 bulk meter connections for wholesale cutomers. Each wholesale customer has, in turn, additional retail connections, but records are available for the largest such customer only. Available connection data are summarized on Table V-1.

Table V-1. City and Satellite Community Connections 1970-1981

Year	Number City Connections	Number Satellite Connections[1]
1970	1901	225
1971	1904	232
1972	1910	246
1973	1922	250
1974	1931	256
1975	1942	260
1976	1958	264
1977	1970	267
1978	1983	270
1979	1990	275
1980	2002	480
1981	2015	403

Source: city water utility

[1]Refers to one major wholesale client; total wholesale clients range from 2 (1970-72) to 13 (1977-81).

Population Forecast

A population forecast prepared for the county water and sewer plan was used. The forecast was made in 1978 and subsequently updated. The population forecast included all planned growth within the service area as well as an expansion of service area boundaries. Adjustments were made to the forecast to best reflect the currently known conditions: population growth rate was reduced to correct for over prediction of 1980 population, the no growth policy of the local college, and the unsuccessful attempts to induce industrial location within the service area.

A 50-year adjusted population forecast appears as Table V-2. It is anticipated that there will be relatively fast growth during the period 1980-1990, then slower growth, levelling off at year 2000 to a growth rate of about 0.5 percent each year.

State College

In order to reflect the role of the local college in water demand, full time college enrollment is converted into the equivalent number of connections, as if the students were living in private homes exhibiting similar water use characteristics as those of the city residents. Enrollment figures were obtained from the Registrar's Office of the college (Table V-3). Only full-time students are counted on the assumption that part-time students are permanent residents of the area and are already included in the census population. The student population is broken down into those who reside on campus and those who live off campus in private homes and apartments.

Among those who live off campus, a further adjustment is made to compensate for possible double counting of local full time students and those who commute from outside the water service area. Such considerations become critical if the local college-bound population is substantial or if the study area is small and surrounded by relatively populous areas. In this study, 25 percent of off campus students are assumed to be local residents (included in Census figures) or commuters from outside the study area.

Adjustments are also made to reflect the duration of academic sessions and other seasonal changes in total population. Before any adjustments can be made, it is important to understand the nature and magnitude of seasonal changes. If the study area has seasonal changes in population (as in college or resort towns), and the duration and magnitude of population change is known, a weighted seasonal population can be added to the permanent residents. In this study, the only seasonal component of the study area is the student population, arising from the difference between the summer and regular session enrollments. Therefore, a weighted average is used:

$$\text{Year round enrollment} = 0.75 \times \text{regular session enrollment} + 0.25 \times \text{summer enrollment.}$$

In addition, an equivalent year round resident number is calculated for both on and off campus students (Table V-4).

Table V-2. Water Service Area Population Forecast
1980-2030

	1980	1990	2000	2010	2020	2030
Existing Service Area	12,579	15,015	15,935	16,900	17,730	18,600
First Stage Expansion[1]	(930)[2]	970	1,000	1,030	1,060	1,090
Second Stage Expansion	(5,040)	(5,750)	6,000	6,250	6,500	6,760
Expanded Service Area	12,579	15,985	22,935	24,180	25,290	26,450

[1]First stage expansion is planned for 1990. Second stage expansion is planned for 2000.

[2]Figures in parentheses represent population in areas prior to becoming part of the expanded service area.

Source: County Water and Sewer Plan and a local water supply study report.

Table V-3. Local College Full-Time Enrollment
1970-1981

Year	Total Enrollment[1]	On Campus	Off Campus
1970	2015	1117	898
1971	2319	1217	1102
1972	1491	1517	974
1973	2625	1584	1041
1974	2793	1576	1217
1975	2792	1608	1184
1976	2851	1773	1078
1977	2810	1760	1050
1978	2959	1884	975
1979	2889	1894	1075
1980	2912	1894	995
1981	2922	1900	1022

[1]Full time graduate and undergraduate students.

Source: Registrar's Office.

Table V-4. Effective City Population
1970-1981

Year	City Population	Off Campus Students	Effective Off-Campus Students[1]	Effective Total City Population[2]
1970	7327	898	593	7920
1971	7365	1102	727	8092
1972	7403	974	643	8046
1973	7441	1041	687	8128
1974	7480	1217	803	8323
1975	7519	1184	781	8300
1976	7558	1078	711	8269
1977	7597	1050	693	8290
1978	7636	975	644	8280
1979	7676	1075	710	8386
1980	7715	995	657	8372
1981	7756	1022	675	8431

Source: State Planning Agency, Registrar's Office.

[1]Effective Off Campus Students = off campus students X adjustment coefficient for local community students (0.75) X adjustment coefficient for year round enrollment (0.88).

[2]Effective Total City Population = city population + effective off campus students.

In this example, information on city population is available from a state planning agency, together with information on average household size. The city population, when added to the off campus student population is divided by the number of city connections to yield an average population per city connection.

$$\text{Average population per city connection} = \frac{\text{city population + off campus students}}{\text{total city connections - wholesale connections}}$$

The effective number of connections for the student population living on campus is calculated by dividing the number of year round equivalent students living on campus by average population per city connection. The total number of effective connections for the city is, therefore (Table V-5):

Effective City Connections = actual number + effective on-campus student connections - wholesale and college connections.

Wholesale Connections

Wholesale water is another issue in this analysis. Each wholesale water client accounts for one connection to the city water supply system. When wholesale water is considered as part of the water supply system, the number of connections served by each wholesale client must be added to the total number of connections in the city. In some cases, this information is available; in others, it must be estimated from population data. Since the demographic characteristics of satellite wholesale clients are somewhat different from those of the city, population per connection must be calculated separately.

The satellite communities served by wholesale water are mostly single family residential homes, where population per connection can be taken as equal to average household size, reported to be 3.1 by the 1980 U.S. Census. Combining this result with satellite area population estimates (from the State Planning Agency) gives estimates of the number of satellite connections for the 1970-81 period. These estimates, combined with total effective city connection estimates, given total effective number of connections, shown on Table V-6.

WATER USE DATA

Twelve years of water use information are available to calculate the per connection use coefficient (Table V-7). Generally, there has been a slight decline in per connection water use, with several exceptions. The local water utility attributed rises in 1977 and to a lesser extent in 1978 to customers opening faucets on cold winter nights to prevent freezing pipes. It is believed that better home insulation has all but ended this practice. Eliminating the 1977 observation for this reason leaves a fairly consistent, slightly downward historic trend in per customer use (Figure V-1). The slight declining trend in water use prevailed in spite of the unchanged nominal water price in the past decade.

Table V-5. Effective City Connections
1970-1981

Year	Effective City Population[1]	Number City Connections[2]	Effective City Population/ Connection	On Campus Students[3]	Equivalent Connections	Effective Total City Connections
1970	7920	1898	4.17	983	236	2134
1971	8092	1901	4.26	1071	251	2152
1972	8046	1903	4.22	1335	316	2219
1973	8128	1918	4.24	1384	326	2244
1974	8323	1919	4.34	1387	320	2239
1975	8300	1929	4.30	1415	329	2258
1976	8269	1945	4.25	1560	367	2312
1977	8290	1956	4.24	1549	365	2321
1978	8280	1969	4.21	1658	394	2363
1979	8386	1976	4.24	1667	393	2369
1980	8372	1988	4.21	1667	396	2384
1981	8431	2001	4.21	1672	397	2398

Source: State Planning Agency, City Water Utility, College Registrar's Office.

[1]City population and effective off campus students, from Table V-4.

[2]Less college connections and wholesale connections.

[3]Corrected for year round enrollment.

Table V-6. Effective Number of Connections for Water Supply System 1970-1981

Year	Effective City Connections	Wholesale Connections	Wholesale Clients	Total Number Connections
1970	2134	254	2	2388
1971	2152	263	2	2415
1972	2219	268	2	2481
1973	2244	317	3	2561
1974	2239	730	11	2969
1975	2258	741	11	2999
1976	2312	781	12	3093
1977	2321	850	13	3171
1978	2363	853	13	3216
1979	2369	1053	13	3422
1980	2385	1054	13	3439
1981	2398	1056	13	3454

Source: City Water Utility; Table V-5.

Table V-7. Per Customer Water Use
1970-1981

Year	Total Water Use (mgd)	Effective Number Connections	Water Use/ Connection (gallons)
1970	0.574	2388	240
1971	0.573	2415	237
1972	0.591	2487	238
1973	0.686	2561	268
1974	0.769	2969	259
1975	0.796	2999	265
1976	0.757	3093	245
1977	0.890	3171	280
1978	0.855	3216	265
1979	0.821	3422	240
1980	0.802	3439	233
1981	0.812	3454	235

Source: City Water Utility; Table V-6.

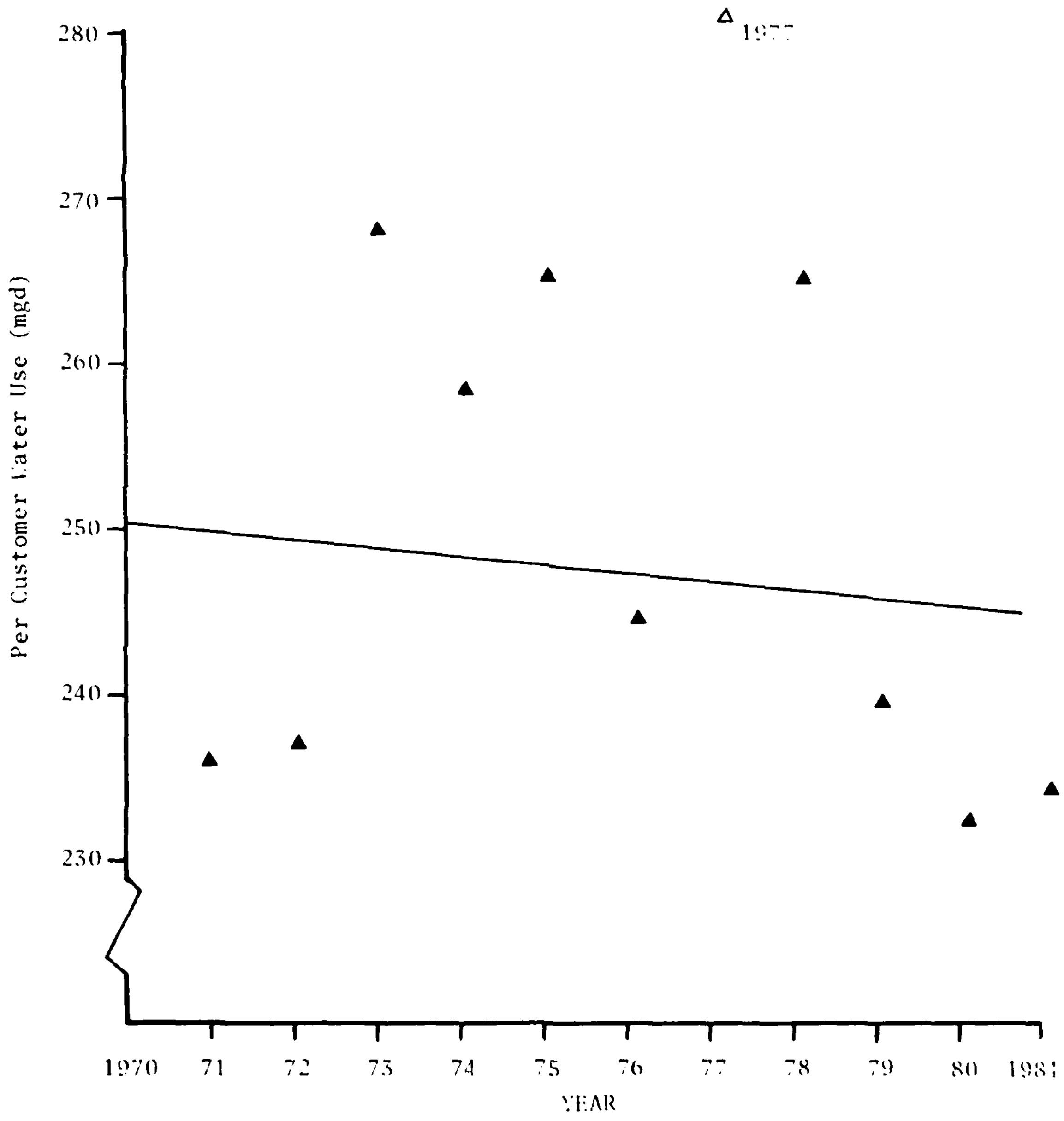

Figure V-1. Historic Trend in Per Customer Water Use, 1970-1981

OTHER INFORMATION

The present water supply system consists of two surface water impoundments with a total storage capacity of 60 million gallons. Raw water is conveyed through a five mile transmission main to the single treatment plant, which has a capacity of 2.0 mgd. It consists of: sedimentation, flocculation, filtration, chemical dosage, and pre and post chlorination processes. There are two treated water reservoirs with a combined capacity of six million gallons.

The storage and distribution system is judged to be adequate for present needs, although system capacity may be inadequate in the event of extended drought. If the service area is expanded, additional capacity and improvements in the distribution system will be required.

In 1979, a computerized billing system was implemented for all customers. All connections within the city are metered. The local college is the major user in the city.

Wholesale water totals about 20 percent of total water demand. There are 13 wholesale clients (satellite communities). No water is imported into the water supply system. Sewage is conveyed by a public collection system to a treatment plant providing secondary treatment and the effluent is discharged to a local stream.

Water rates have remained essentially unchanged during the past decade, utilizing an increasing block rate structure. In real terms, water rates have decreased with respect to other prices. Wholesale water rates are slightly higher than those inside the City, although they decline at high volumes.

No conservation measures are in effect at the present time, or planned for future implementation. Had one or more measures been proposed, it would have been necessary to determine the effect of that measure with respect to per connection water use. This could be based on previous local experience with partial implementation or on experience in similar communities elsewhere. Such a determination can only be approximate, at best.

If data from another area are found, expressed on a per connection or per capita basis, which describe the effectiveness of a similar measure, those data could be used to estimate effectiveness in the study area. If the service area from which the data were collected had a markedly different structure of water use, however, the results could be seriously biased. For example, noting that a residentially-oriented measure reduces per capita water use by 5.0 gpcd is not complete information. It is also necessary to know what fraction of total water use is residential, so that differences in water use structure can be accounted for. In the absence of this information, effectiveness determinations must be made cautiously, with some understanding of the range of possible error. As forecasts become more disaggregated, as demonstrated in Sections VI through VIII, the reliability of effectiveness estimates improves.

Water Use Forecast

A forecast of water use for the study area requires projections of the number of connections and of water use per connection for each forecast year. The connection projection is based on the population forecast shown on Table V-2, and a projection of population per connection derived from an existing projection of average population per household, adjusted to population per connection on the basis of 1980 data. Projected number of connections for each forecast year is, therefore, projected population divided by projected population per connection.

In projecting water use per connection, it is important to consider, at a qualitative level, other variables which may affect future water use. In this forecast, the planned growth and expansion of the service area, expected to occur in two stages, is well documented in the county water and sewer plan and in the county comprehensive plan. Socio-economic and land use information is also available from these sources. Since no substantial deviations from recent trends are expected for most demographic and socio-economic variables, future water use per connection is obtained by a simple extrapolation of the recent trend shown on Figure V-1.

A linear extrapolation of per connection water use is illustrated on Figure V-2. The trend line is fitted through the data points plotted on Figure V-1, giving a coefficient value which decreases slowly over time. However, due to the large variance of the residual (that is, excessive scatter of points around the trend line) the result is less than fully satisfactory. Apparently factors not considered in this analysis, such as weather, local economic conditions, changes in housing mix, price level, etc., affect the coefficient value. After qualitative re-examination of these issues, no basis was found for modifying the coefficient projection.

The results of parameter and coefficient projections, together with the resulting water use forecast, are shown on Table V-8. Population projections are obtained from Table V-2, and population per connection is forecast as described above. These projections lead to estimates for number of connections for each forecast year. When multiplied by projected per connection water use, this gives the water use forecast for each year plotted as Figure V-3. Forecast average day water use can be seen to rise from 0.811 mgd in the base year to 1.673 mgd in the year 2030, an average annual increase of almost 1.5 percent/year over the 50 year planning period.

Analysis of Results

PROCEDURAL PROBLEMS

The per connection requirement method described here is one of many possible approaches to the forecasting problem. It may be relevant to point out that the per connection method can easily be transformed into the per

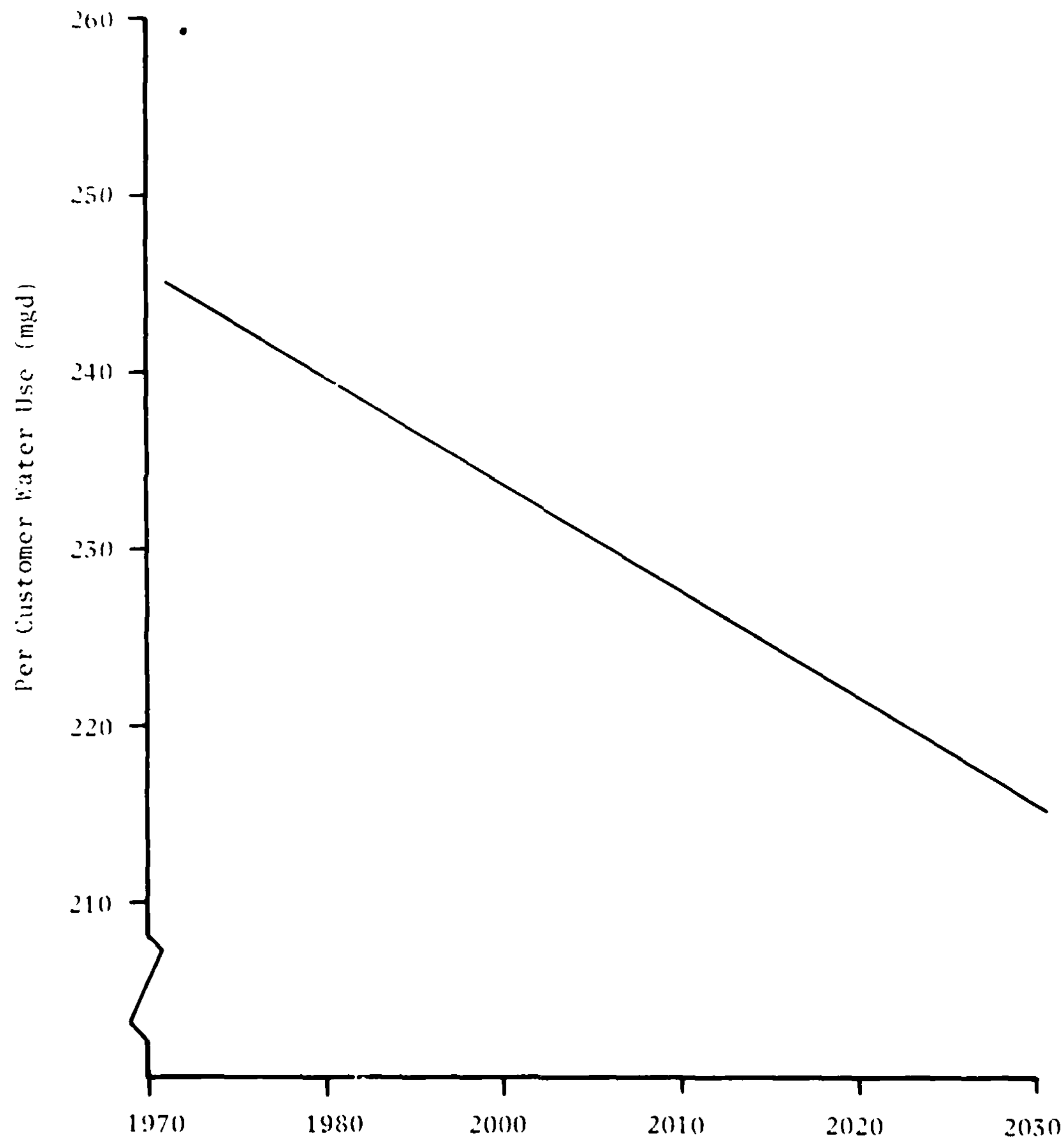

Figure V-2. Forecast of Per Customer Water Use, 1981-2030

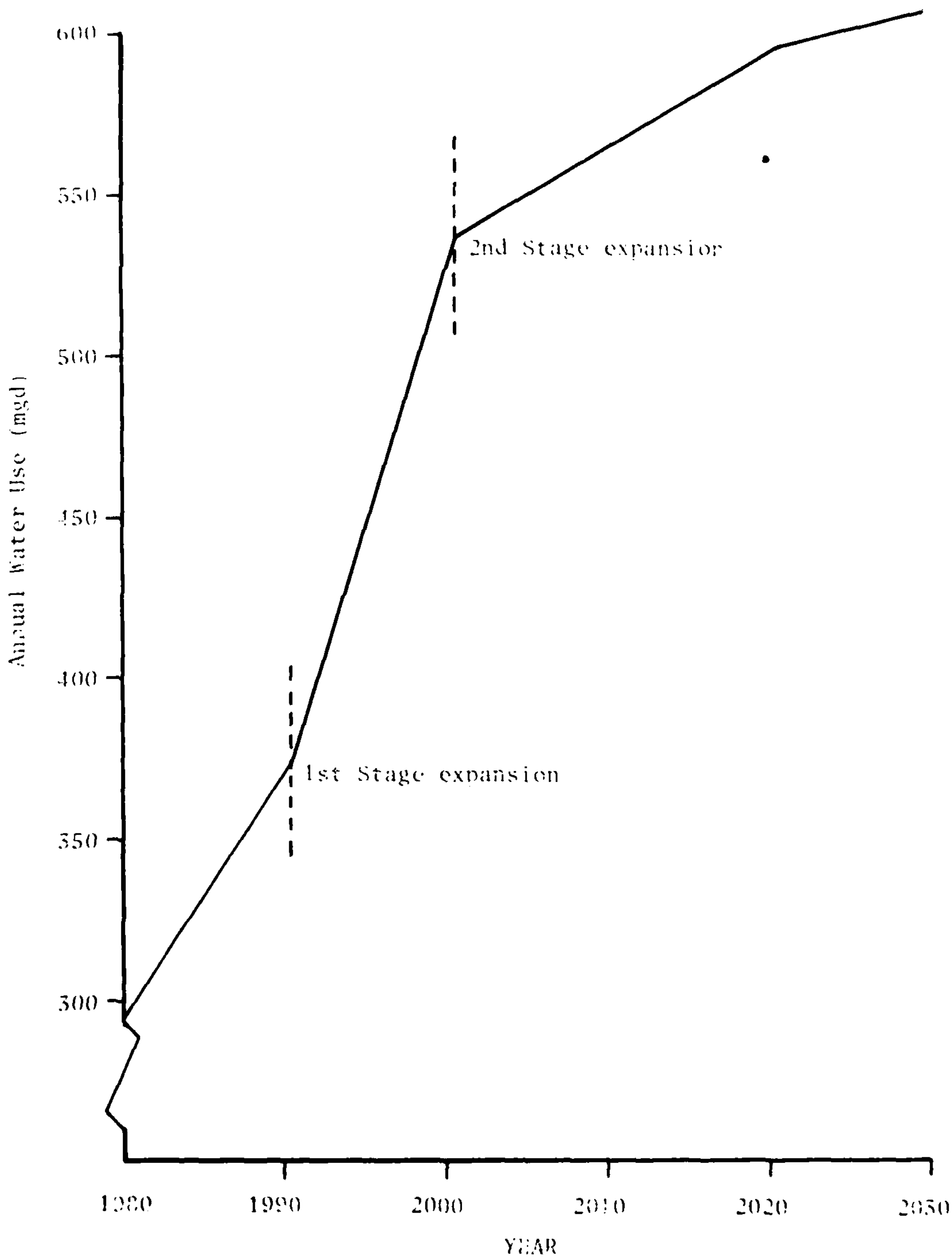

Figure V-3. Forecast of Annual Water Use, 1980-2030

Table V-8. Forecast Water Use
1980-2030

	1980	1990	2000	2010	2020	2030
Projected Population[1]	12,579	15,985	22,935	24,180	25,290	26,450
Population Per Connection[2]	3.8	3.7	3.6	3.5	3.4	3.4
Projected No. Connections	3,310	4,320	6,370	6,910	7,440	7,780
Per Connection Water Use[3]	245	239	233	227	221	215
Daily Water Use (mgd)	.811	1.032	1.484	1.569	1.644	1.673
Annual Water Use (mg)	296	377	542	573	600	611

[1]From Table V-2.

[2]A weighted average between city and satellites.

[3]Decreasing rate of 0.6 gallon per year, see Figure V-2.

capita method. In this study, for example, the total population of the study area could have been multiplied by a per capita use coefficient, projected in a manner exactly analogous to the per connection coefficient used. This approach was not adopted because of its reliance on historic population figures to obtain per capita values. The lack of accurate historic population data, and lack of information on historic service area boundaries, would render the estimate of a per capita coefficient unreliable and any forecast based on this coefficient could further amplify the errors in estimation that may be present. The choice of the per connection requirement method fully utilizes the set of reliable data that were available for the largest part of the service area: the number of connections, and historic water use.

SENSITIVITY ANALYSIS

Two coefficients are critical to the outcome of the forecasting method: average population per connection and water use per connection. Average population per connection is needed to convert the projected population at each period to the number of connections. Any error in estimation will affect the accuracy of the projected total water demand. Knowledge of the socio-economic conditions of the present service area together with those of anticipated growth areas and projected population could improve the accuracy of the population per connection coefficient. The slow growth of the city, the current no-growth policy of the college, and the expansion of service area into surrounding residential area imply upper and lower bounds for the population per connection water use coefficient. At one extreme, the coefficient is bounded by the calculated present population per connection, and at the other end, by the average household size and its projections available through the Census.

Water use per connection is a function of land use and economic activities, given the constant and uniform effect of climate, price of water and income over time. It is difficult to predict trends in water demand if there is a heterogeneous mix of land use and economic activities, and if each sector is expected to grow at a different rate. For this study, residential water use is expected to dominate the study area, and growth is expected to be similar to those of surrounding areas. Per capita water use of about 60 gallons per day is implied by the per connection water use coefficient used.

DETAIL vs. AGGREGATION

The forecast results can never contain more information than that originally represented by the data and assumptions. The amount of information derived from the procedure is a function of the level of information available initially. Aggregate data yielding average water use per connection is employed in this study. The result is the projected aggregate water use per connection. It is not possible to draw conclusions of greater detail than those supported by the data.

WITH- vs. WITHOUT-PROJECT CONDITIONS

The forecast described in this section was performed as part of a preliminary assessment of water supply and demand conditions. Since no projects were being planned, no with-project forecast is applicable. Had such a forecast been required, however, the method chosen (the per connection method) offers limited scope for reflecting the impact of a federally-planned water supply project on future water use. Most affected variables (price, economic development, etc.) are not explicit in the forecast, and reliance must be placed on qualitative analysis, followed by subjective adjustments to the per connection water use coefficient. Such adjustments must be approached with care, as they are likely to be unreliable, and may erode the credibility of the resulting forecast.

APPLICATION OF RESULTS

The procedure described here, based on level 1 data, gives a forecast of aggregate water use. It does not provide information on growth and demand in particular sectors of the community. It cannot differentiate water use from the city, the college, or the satellites, which are known to be different in character. The results are appropriate only to a preliminary study, which is not governed by the *Principles and Guidelines*. A study of this kind may give indications of project needs and feasibility, given the assumptions of the forecasting method and the level of data aggregation. In order to complete the planning process for a specific project, a more detailed study must be undertaken at a later date.

COMPARISON WITH OTHER FORECASTS

When compared to other water use forecasts for the study area, the results for this study show somewhat lower forecast water use than results from a consultant report, or from the county water and sewer plan (Table V-9). The consultant study assumed both more rapid population growth and higher water use rates. It forecasted a 130 percent increase in water use over 40 years, an average rate of about 2.1 percent/year. The county assumed industrial water use of 0.5 mgd (actual use in the base year was no more than 0.03 mgd) as well as sustained growth for the local college.

A consultant's report for the same study area suggested higher water use in 1990, and nearly identical use in 2000. Although similar population forecasts were used, the consultant report, employing the per capita method, assumes slowly increasing unit use rates in the future, while this study implies a nearly static per capita use rate over the 50 year planning period.

Table V-9. Comparison With Other Forecasts

(average day mgd)

Year	Example A	Consultant Study	County Water and Sewer Plan
1980	0.811	0.818	1.07
1990	1.032	1.346	1.35
2000	1.484	1.425	1.43
2010	1.569	1.664	-
2020	1.644	1.894	-
2030	1.673	-	-

VI. EXAMPLE B – LEVEL 2 DATA

Background and Approach

STUDY AREA

Example B is a forecast prepared for a city of approximately 400,000 located in the south central U.S. The study area is inland at an elevation of 700 feet above sea level; it is surrounded by gently rolling hills and several large lakes. The climate is continental, characterized by rapid changes in temperature. Winters are mild, with an average temperature for the winter months of 39.4°F; summer months average 80.8°F and temperatures of 100°F or higher are frequently experienced. Average annual temperature is about 60°F. Rainfall is moderate (averaging 37 inches per year) and generally seasonal, with monthly averages ranging from 1.7 inches in winter to 4.1 inches in spring. Average snowfall is less than 10 inches per year. The area is subject to violent windstorms and tornadoes, which occur throughout the year.

The study area is defined as the service area of a municipally-owned water utility, adjusted to include the major industrial water users in the metropolitan area. The utility service area is essentially identical to the corporate limits of the city; those industrial users located outside the city limits are served through the distribution systems of suburban utilities (wholesale customers of the city utility) or by private pipeline. The study area includes approximately 70 percent of the metropolitan area population, and more than 90 percent of industrial employment.

The relative sizes of the major employment sectors within the study area are indicated on Table VI-1. Data shown are the percentage of total labor force engaged in each sectoral activity. Manufacturing and service sectors together account for 40 percent of total employment. The major industrial employers are the energy and transportation industries. Oil and oil-related activities account for some 30,000 employees within the study area, while over 10,000 people are employed by aviation and aerospace firms.

High rates of growth have been experienced by the local economy in the past, and are expected to continue into the medium-term future. The study area includes large tracts of undeveloped land, creating a potential for substantial growth during the forecast period.

FORECAST REQUIREMENTS

The forecasting method chosen for this example must provide the necessary information to the planning process, be sensitive to factors which are important determinants of water use in the study area, and make the best use of data which can reasonably be made available. In the case of the first

Table VI-1. Distribution of Study Area Employment, 1981

Activity	Size of Activity (Employment) Percentages
Manufacturing	20
Services	20
Retail Trade	16
Government	10
Transportation, Utilities	8
Wholesale Trade	7
Mining	7
Construction	6
Finance, Insurance, Real Estate	5
Agriculture	1

Source: Economic Outlook for the City, Published by the Economic Development Commission requirement, forecasts of municipal and industrial water use are needed for a 50 year planning period, beginning in 1980. No further disaggregation is required, as no conservation measures are to be evaluated. Because current planning is concerned with the adequacy of sources, rather than facilities, only average day water use must be forecast.

The study area has experienced very rapid growth in all measures of water use during the past decade, and the forecast method should be capable of identifying components of that growth so that future trends can be properly projected. Also, water use in the study area is highly seasonal, so the method should be able to treat seasonal water use in an appropriate way.

A preliminary assessment of data availability indicates that good quality data on daily water pumpage are available for past years, as well as data on water sold to areas outside of the study area, and on industrial water use. Data are also available for various explanatory variables, including weather variables.

Based on these conditions, a multivariate requirements model was attempted, with the explanatory variables to be selected from the limited set available without extensive data collection. These include resident population, number of connections, industrial employment, average monthly temperature, average monthly rainfall, monthly moisture deficit, number of household units, household size, and value of building permits. Municipal water use is forecast separately from industrial use, and municipal water is further disaggregated into seasonal and non-seasonal components. As described below, no multivariate model could be formulated; the forecast is performed by a series of single coefficient models. The coefficients of the models are estimated by times-series analysis, using data from the period 1970-1981.

Data Collection

EXPLANATORY VARIABLES

Four possible sources of population data and projections are available: decennial U.S. Census data, locally adjusted annual population data, OBERS projections for the SMSA, and an estimate of service area population based on number of connections. OBERS population data are not used, as the service area comprises less than 70 percent of the SMSA population, and the city and surrounding counties have had widely different growth rates in the past.

Census data, on the other hand, can be adjusted to match the service area of the utility, which is nearly identical to the city itself. This process gives population for the years 1970 and 1980, which can be interpolated with the help of local information, such as rate of change in number of connections. Resulting study area population ranges from 365,037 in 1970 to

398,815 in 1980, an average annual increase of about 0.9 percent. Annual estimates are summarized later in this section.

The number of connections to the distribution system is available on a continuous basis from the records of the water utility. The total number of connections has increased from 111,789 in 1970 to 136,131 in 1980, an average annual increase of about 2.0 percent. The disparity in growth rates between population and number of connections results from (1) very rapid growth in nonresidential connections during the decade (commercial and institutional growth, primarily) and (2) decreasing household size, resulting in fewer persons per residential connection.

Other demographic data were obtained from local sources, including total number of household units and average annual value of building permits issued. These data are shown on Table VI-2, together with the calculated average household size. It can be seen that the total number of households increased dramatically during the 1970-1980 period, accompanied by a rapid drop in average household size.

Industrial employment also increased rapidly during the past decade. Employment totals for an industrial sector including manufacturing, transport, and some service activities were obtained from state agencies and from certain federal data pertaining to the SMSA. Total industrial employments as defined here, rose from 81, 827 in 1970 to 116,838 in 1980, an average rate of growth of 3.6 percent per year.

Data were also collected on average monthly temperature and average monthly precipitation for the study area. These data are shown as Tables VI-3 and VI-4. Monthly moisture deficits are calculated from temperature and precipitation data, using the method of Thornthwaite and Mather (1957) for potential evapotranspiration and effective precipitation as defined below (from Linsley and Franzini [1964]). Moisture deficit is shown on Table VI-5, and is defined as:

$$MD = PE - EP \qquad \text{(VI-1)}$$

$$EP = AP \text{ (actual precipitation) if } AP \leq 1 \text{ inch}$$
$$= [-0.1(AP)^2 + 1.2(AP) - 0.1] \text{ if } 1 < AP < 6 \text{ inches} \qquad \text{(VI-2)}$$
$$= 3.5 \text{ if } AP \geq 6 \text{ inches.}$$

Where: MD = monthly moisture deficit (inches)
PE = monthly potential evapotranspiration (inches)

WATER USE DATA

Total water use (total pumpage into the distribution system) is made up of municipal and industrial sectors. Municipal water use represents metered water use (by residential, commercial, and institutional users) and unmetered public and unaccounted uses. Industrial water use represents treated water supplied to large industrial users.

Table VI-2. Housing Units and Value of Building Permits, 1970-1980

	Number of Housing Units[1]	Household Size[2]	Average Value of Building Permits[3] ($1,000,000)
1970	121,362	3.01	120.1
1971	126,613	2.92	113.4
1972	131,911	2.83	179.6
1973	137,952	2.73	210.6
1974	141,455	2.68	231.8
1975	143,763	2.66	105.7
1976	147,049	2.62	192.3
1977	150,824	2.58	240.5
1978	154,706	2.53	408.8
1979	158,331	2.50	289.8
1980	161,809	2.46	443.7

[1]Obtained from the water utility.

[2]Population of service area (Table VI-9) divided by the number of housing units.

[3]Obtained from the water utility.

Table VI-3. Average Temperature 1970-1980. (°F)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1970	29.7	41.9	44.6	60.7	70.7	76.9	82.8	84.8	74.5	58.9	45.6	42.5
1971	36.5	39.0	49.9	60.2	66.7	79.4	80.0	79.0	73.0	65.0	50.1	43.7
1972	34.8	41.8	53.0	62.8	68.0	79.5	80.4	81.7	75.5	60.9	43.6	33.7
1973	34.0	39.8	54.3	58.2	67.5	76.7	81.2	79.3	72.3	65.0	53.4	38.1
1974	34.1	43.7	55.2	61.8	72.1	73.8	85.4	78.3	64.7	63.0	49.1	39.7
1975	39.9	36.9	45.3	60.4	69.1	76.0	81.2	82.2	69.2	63.2	50.8	40.1
1976	37.2	51.1	51.9	61.5	63.0	75.0	81.4	79.7	72.8	56.1	43.1	37.1
1977	26.9	46.6	55.0	64.4	72.6	81.0	84.8	81.7	75.6	62.2	51.1	39.0
1978	24.9	29.4	47.5	63.5	68.3	77.6	87.8	84.3	80.6	63.5	51.6	38.0
1979	23.1	30.2	52.4	61.0	68.7	77.8	83.4	81.8	74.7	66.2	47.5	44.4
1980	38.6	37.1	48.3	61.1	70.6	82.5	91.7	89.7	78.3	61.5	50.5	42.3

Table VI-4. Total Rainfall 1970-1980, (inches)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1970	0.41	0.57	2.05	5.66	4.20	4.60	0.13	1.85	6.37	5.83	0.84	1.15
1971	1.37	4.18	0.08	1.37	6.59	3.27	3.34	1.86	18.81	7.99	1.21	6.34
1972	0.17	0.49	0.91	4.45	2.43	2.69	2.68	5.16	2.95	7.58	5.00	1.03
1973	3.39	0.74	11.94	7.22	5.30	7.69	6.47	4.70	6.56	6.16	6.32	3.39
1974	0.79	3.17	2.62	3.65	6.94	7.88	0.55	5.30	11.78	6.40	7.30	2.88
1975	2.61	3.44	5.45	2.20	7.22	6.75	2.14	3.52	3.34	1.47	3.53	3.04
1976	0.21	0.84	3.95	8.27	6.75	1.87	4.37	1.17	2.60	2.65	0.68	0.55
1977	1.43	1.57	5.58	2.05	5.72	6.69	2.00	4.86	5.57	2.75	2.31	0.93
1978	0.81	2.84	2.99	7.14	9.28	6.06	0.36	1.37	0.13	0.95	5.48	0.78
1979	2.07	0.81	3.97	4.47	6.15	8.90	2.68	4.77	0.28	2.20	5.60	0.45
1980	2.07	1.32	3.59	3.44	7.23	5.57	0.09	2.34	3.47	2.05	0.79	1.37

Table VI-5. Moisture Deficit 1970-1980, (inches)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1970	-0.41	-0.31	-0.61	-1.09	1.86	3.10	7.31	6.20	1.14	-1.46	-0.32	-0.19
1971	0.82	-2.24	1.16	1.49	0.13	4.63	4.70	4.81	0.83	-0.88	0.53	-3.00
1972	-0.17	-0.23	0.33	0.30	2.53	4.98	5.09	3.51	2.87	-1.17	-2.48	-0.62
1973	-2.03	-0.48	1.95	-1.52	0.81	2.36	3.20	3.46	0.83	-0.88	-2.21	-2.03
1974	-0.79	-1.39	-0.02	0.45	1.22	1.99	7.26	2.72	-0.72	-0.88	-2.73	-1.48
1975	-1.31	-2.10	-2.65	0.99	0.49	2.36	5.42	4.41	1.40	1.74	-1.07	-1.57
1976	-0.21	0.18	-1.13	-0.86	-0.23	4.37	4.08	5.56	2.77	0.16	-0.16	-0.55
1977	-0.86	-0.43	-1.80	1.74	1.29	3.09	6.61	3.71	1.30	0.39	-0.62	-0.68
1978	-0.81	-1.70	-1.17	-0.86	0.49	2.72	7.82	6.14	5.43	1.38	-2.27	-0.78
1979	-1.24	-0.81	-1.16	-0.37	0.49	2.72	5.83	3.75	4.36	1.59	-3.18	0.05
1980	-1.24	-0.79	-1.84	-0.74	-0.23	3.98	8.47	6.60	3.15	-0.07	-0.53	-0.82

The water use data for the study area are presented in Table VI-6. Total water use measures total water pumped into the distribution system. The breakdown of water usage in 1980/81 is as follows:

Industrial	37.8%
Municipal	
residential/commercial	42%
public	3.3%
unaccounted	16.9%

Table VI-7 shows the changing levels of public and unaccounted water, measured as percentages of total water use for each year. The percentage of total water used by the public sector has remained fairly constant over the past six year's averaging 3.8 percent. Unaccounted water has been more variable ranging from 14.3 percent in 1976/77 to 21.4 percent in 1979/80. Residential/commercial water use was calculated by subtracting industrial, public, and unaccounted use from total water use.

In 1980, the 22 largest industrial water users in the study area accounted for 9,284.5 mg or 25.4 percent of total water use. These firms represent 68 percent of total industrial water use. Total water used by the industrial sector is 13,819.6 mg or 37.8 percent of total water use.

Strong seasonal variations in water use are evident from examination of monthly pumpage figures. In the absence of other data, it is assumed that these variations occur entirely within the municipal sector. Table VI-8 shows seasonal variations in municipal water use for each year, calculated according to the formula:

$$q_{si} = q_i - q_{ni} \qquad \text{(VI-3)}$$

Where: q_{si} = seasonal municipal water use in year i
q_i = total municipal water use in year i
q_{ni} = nonseasonal water use in year i (average monthly water use for December-March times 12)

Column 1 in Table VI-8 gives computed water use figures equal to the excess of total municipal water use over nonseasonal use. The results from Table VI-8 are graphed in Figure VI-1. The seasonal variations suggest high correlations between summer weather and water use. Steady increases are evident for both seasonal and nonseasonal water use over the past decade.

OTHER INFORMATION

High rates of growth for the local economy are predicted for the 1980's. Personal income is expected to rise at an annual rate of 4.3 percent for the SMSA and 5.4 percent for the county. It is predicted that manufacturing employment for the region will increase by 3.8 percent and service employment by approximately 4 percent per year. It is expected that the population of the SMSA will grow by 2.3 percent; that of the county by 1.7 percent; and

Table VI-6. Annual Water Use Data, 1970-1980 (mg/year)[1]

	Total Water Use	Municipal: Residential/[2] Commercial	Municipal: Public Unaccounted	Municipal: Total	Industrial
1970	21,131.7	8,955.2	4.325.5	13,280.7	7,851.0
1971	21,195.4	8,982.2	4,338.5	13,320.7	7,874.7
1972	22,522.7	9,544.7	4,610.2	14,154.9	8,367.8
1973	22,928.6	9,716.7	4,693.3	14,410.0	8,518.6
1974	24,949.9	10,573.3	5,107.0	15,680.3	9,269.6
1975	26,313.0	11,638.7	4,945.3	16,584.0	9,729.0
1976	27,743.3	12,391.3	5,088.9	17,480.2	10,263.1
1977	29,816.8	13,383.2	5,404.6	18,787.8	11,029.0
1978	32,770.3	13,190.7	7,453.1	20,643.8	12,126.5
1979	34.751.8	13,205.7	8,671.9	21,877.6	12,874.2
1980	36,546.2	15,342.4	7,384.2	22,726.6	13,819.6

[1]Total water pumpage data obtained from the water utility on a daily basis, and totaled over each calendar year.

Table VI-7. Percentage Changes in Public and Unaccounted Water Use By Sector[1]

	Public[2]	Unaccounted
1975/76	4.1	14.7
1976/77	4.0	14.3
1977/78	4.3	13.8
1978/79	3.8	19.0
1979/80	3.6	21.4
1980/81	3.3	16.9
Total average percentage change	3.8	16.7

[1]Each value represents the percentage of total water supplied accruing to that sector for each year.

[2]Water sold to the city government for public uses.

Source: Previous water use forecast for the service area.

Table VI-8. Seasonal and Non-Seasonal Municipal Water Use, 1970-1980 (mg/year)

	q_{si} [1]	q_{ni} [2]
1970	1,769.0	11,511.7
1971	1,601.5	11,719.2
1972	1,833.8	12,321.1
1973	1,547.2	12,862.8
1974	1,782.1	13,898.2
1975	2,199.5	14,384.5
1976	1,694.4	15,785.8
1977	2,187.8	16,600.0
1978	3,170.7	17,473.1
1979	2,038.4	19,839.2
1980	2,364.5	20,362.1

[1]Seasonal water use is excess of total water use over non-seasonal.

[2]Non-seasonal = December - March average times 12.

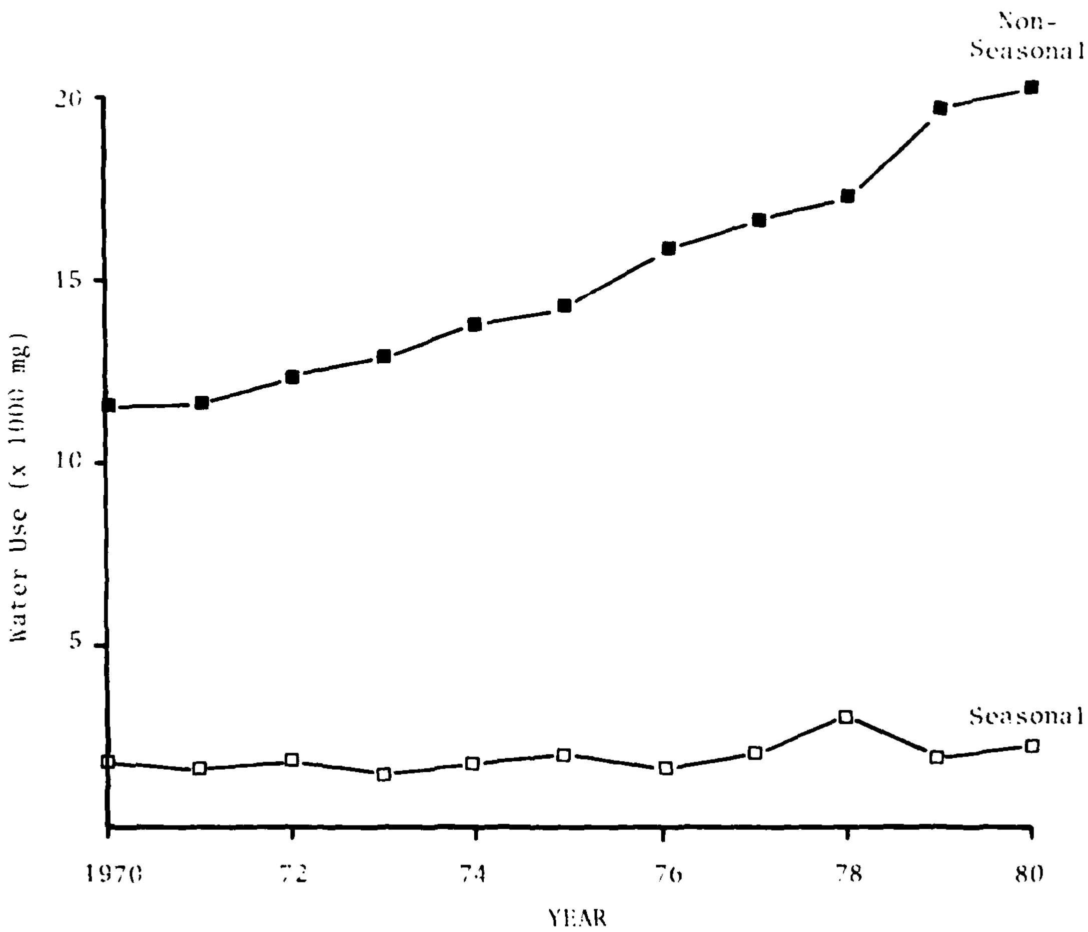

Figure VI-1. Seasonal and Non-Seasonal Municipal Water Use, 1970-1980 that of the city by 1 percent per year. The rate of residential construction has slowed over the last few years although there have been very high levels of non-residential construction. Multi-family residential structures have increased at a greater rate than single-family structures.

Two city-owned impoundments provide the main supply of water to the study area. Together these two impoundments have a dependable yield of 60 mgd. In 1964, the water utility received an appropriation of water rights for an additional 66 mgd to be withdrawn from a third reservoir. In total, the utility has a dependable supply of 126 mgd. There is also a contract for emergency supply from another river in the event of a severe drought.

There are two water treatment plants in the distribution system. Currently, these plants have a combined treatment capacity of 150 mgd and pumping capacity of 162 mgd. The distribution system is being upgraded and the capacity of one of the treatment plants is to be increased by 40 mgd. The raw water supply pipelines have a combined capacity of 140 mgd.

The present water supply available to the utility is insufficient to handle expected future increases in water use. In 1980-81, a severe drought occurred and reservoir levels became so low that raw water had to be pumped from the emergency supply source.

Existing water use forecasts for the service area indicate that demand will equal existing supplies in 1983. The water utility has recently applied for water appropriation rights from an additional (fourth) source. If these rights are secured, demand will not exceed supply until 1991, at present growth rates.

Customers in the study area are charged a fixed rate or minimum bill for the first 1,000 gallons consumed, after which they are charged a constant rate per unit of water used (uniform rate structure with minimum bill).

Water Use Forecast

MODEL FORMULATION

In order to develop water use models suitable for forecasting, historical relationships between water use and various explanatory variables are investigated. Bivariate relationships (between water use and a single explanatory variable) are examined first, so that variables having the highest correlations with water use can be retained for later use in the model. Total municipal water use is reviewed, followed by separate consideration of seasonal and non-seasonal components. Industrial water use is examined separately.

Per Capita Use

Per capita rates of daily municipal water use are presented in Table VI-9. These figures are calculated by dividing daily municipal use by the estimated population of the service area. Per capita use increases from 99.7 gpcd in 1970 to 155.7 gpcd in 1980. These data indicate an unusually large average annual percentage increase of 4.6 percent over the past ten years. If residential/commercial use is isolated, per capita rates are reduced to 67.2 gpcd for 1970 and 105.4 gpcd in 1980, although average annual growth remains at approximately 4.6 percent. Figure VI-2 shows that the rate of increase in per capita municipal use accelerates after 1975. This is reflected in the annual percentage increase for the years 1975-1980 of 5.5 percent per year, compared to an increase of 3.6 percent per year between 1970 and 1975.

Per Connection Use

The number of connections, water use per connection and population per connection are shown in Table VI-10. Water use per connection (see Figure VI-3) has increased sharply over the past ten years, although the percentage increase (3.4 percent per year) is somewhat less than that of per capita use. Population per connection (Figure VI-4) shows a steady decrease over the past 10 years. This is an expected result as household sizes (number of residents per dwelling unit) have been generally decreasing (Table VI-2).

Per Employee Industrial Use

Industrial employment, water use and water use rates are presented in Table VI-11. The industrial sector includes manufacturing, transport and certain service industry components. Water use per employee ranges from 262.9 gallons per day to 323.2 gallons per day, an average increase of 2.1 percent per year. This growth, while substantial, is noticeably less than the per capita and per connection increases in the municipal sector. Figure VI-5 shows the change in industrial water use rates over time.

Water Use Models

Municipal Water Use: Municipal water use is divided into seasonal and non-seasonal components (see Table VI-8). Seasonal and/or total municipal water use can be expressed as a function of at least seven explanatory variables: population, number of connections, household size, average annual value of building permits and three weather variables: temperature, precipitation, and moisture deficit. Non-seasonal water use can be expressed as a function of these same variables with the exception of weather data. This is because it is expected that sprinkling water use, which is weather-related and comprises a major component of seasonal water use, will be

Table VI-9. Population, Daily Municipal Water Use, Per Capita Use, 1970-1980

	Population of the Service Area[1]	mgd[2]	Per Capita Use/Day[3]
1970	365,037	36.39	99.7
1971	369,114	36.50	98.9
1972	373,087	38.67	103.6
1973	376,249	39.48	104.9
1974	379,228	42.96	113.3
1975	382,197	45.44	118.9
1976	385.403	47.76	123.9
1977	388,600	51.47	132.4
1978	391,987	56.56	144.3
1979	395,106	59.94	151.7
1980	398,815	62.09	155.7

[1]Estimates obtained from planning agencies in the service area and U. S. Census.

[2]Total annual municipal use (Table VI-6) divided by the number of days per year.

[3]Daily consumption divided by the population of the service area.

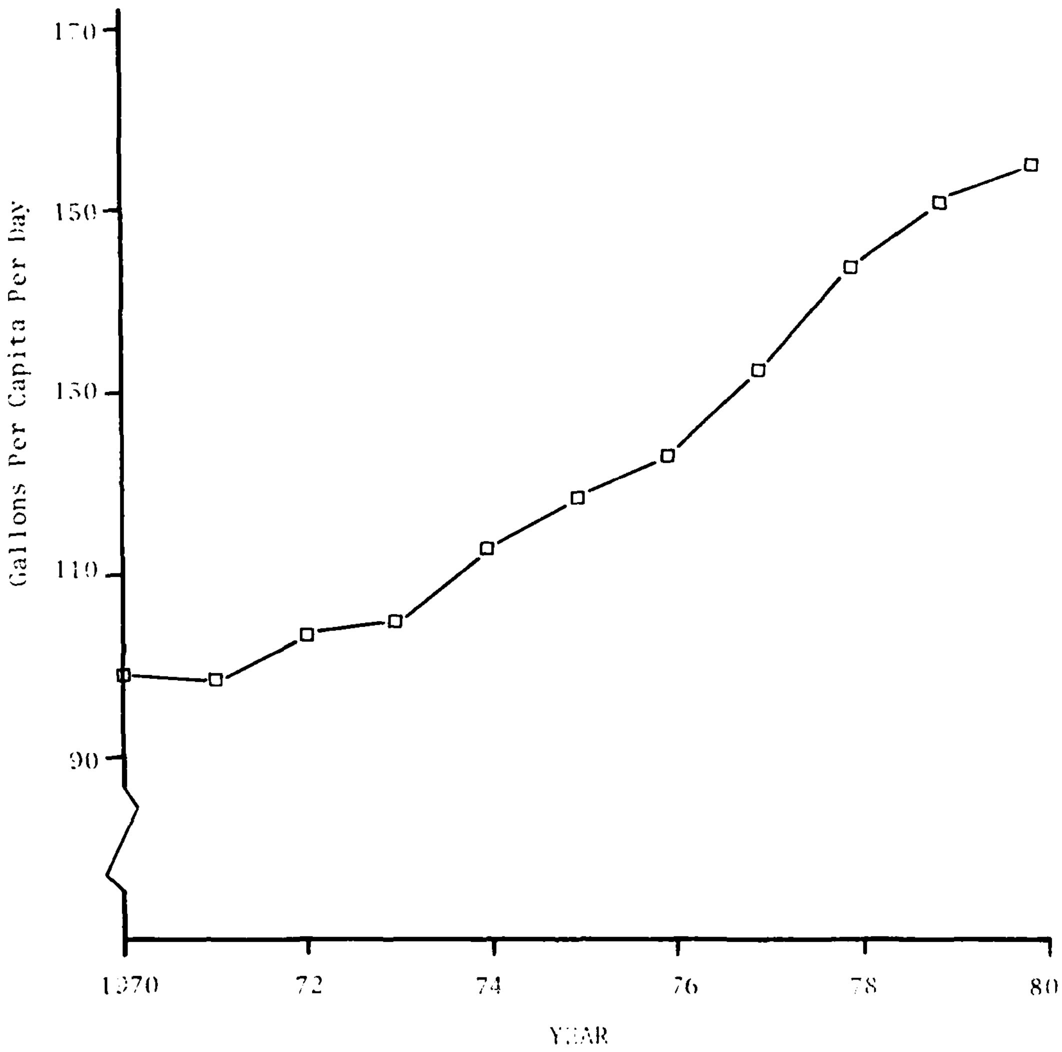

Figure VI-2. Per Capita Municipal Water Use Rate, 1970-1980

Table VI-10. Number of Connections, Water Use Per Connection and Population Per Connection, 1970-1980

	Number of Connections[1]	Water Use Per Connection[2] gpd	Population Per Connection[3]
1970	111,789	325.5	3.27
1971	115,183	316.9	3.20
1972	117,467	329.2	3.18
1973	121,009	326.3	3.11
1974	123,064	349.1	3.08
1975	124,628	364.6	3.07
1976	125,914	379.3	3.06
1977	127,519	403.6	3.05
1978	129,598	436.4	3.02
1979	132,812	451.3	2.97
1980	136,131	456.1	2.93

[1]Provided by water utility.

[2]mgd (Table VI-9) divided by the number of connections.

[3]Population of the Service Area (Table VI-9) divided by the number of connections.

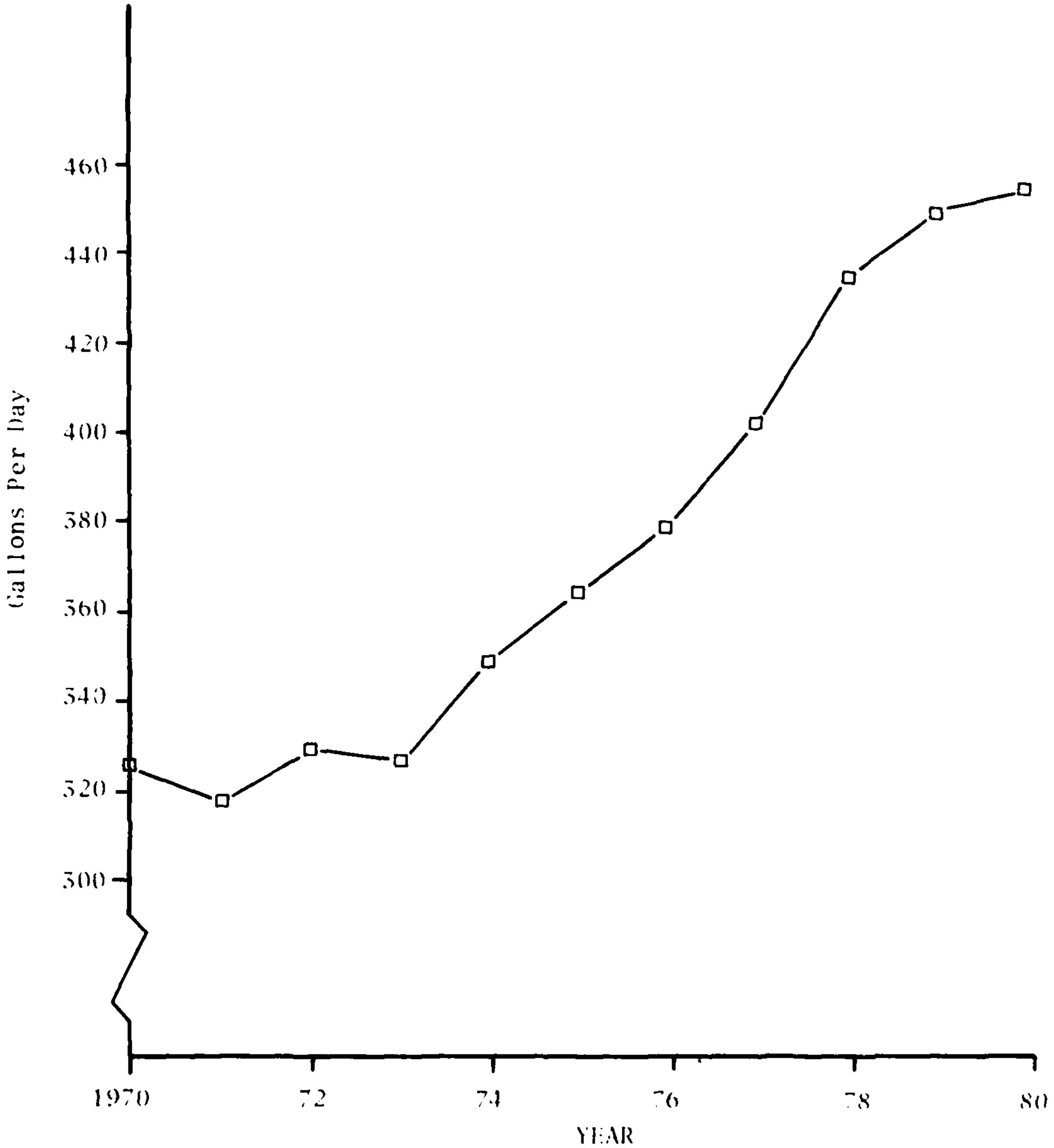

Figure VI-5. Municipal Water Use Per Connection, 1970-1980

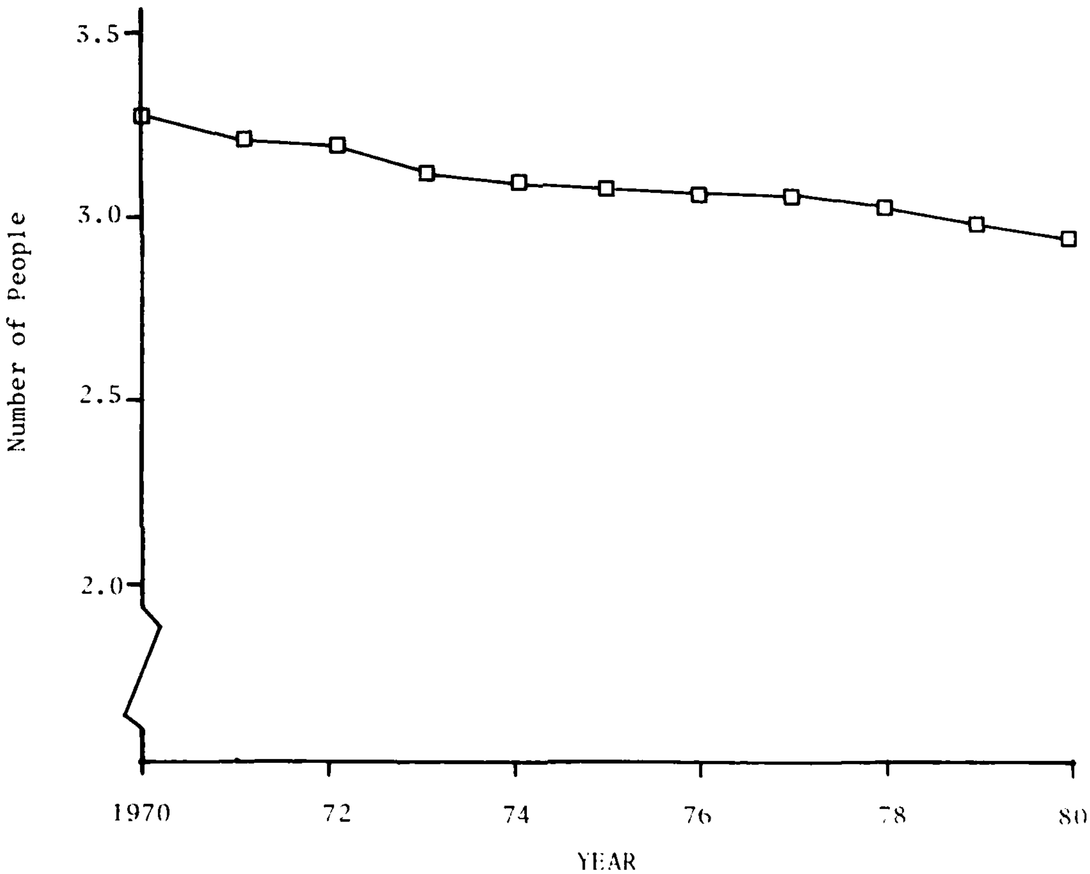

Figure VI-4. Population Per Connection, 1970-1980

Table VI-11. Industrial Employment, Water Use and Water Use Rates, 1970-1980

	Employment[1]	Industrial Water Use[2] (mgd)	Industrial Water Use/ Employee gpd
1970	81,827	21.51	262.9
1971	80,567	21.56	267.6
1972	82,864	22.86	275.9
1973	86,647	23.34	269.4
1974	92,283	25.40	275.2
1975	94,157	26.65	283.0
1976	98,408	28.04	284.9
1977	102,123	30.22	295.9
1978	106,173	33.22	312.9
1979	112,313	35.27	314.0
1980	116,838	37.76	323.2

[1]Represents manufacturing employment, transport and utilities and some service employment. Source: OBERS historic data for the SMSA and data from stage government departments.

[2]Annual water use for the industrial sector divided by the number of days per year (from Table VI-6).

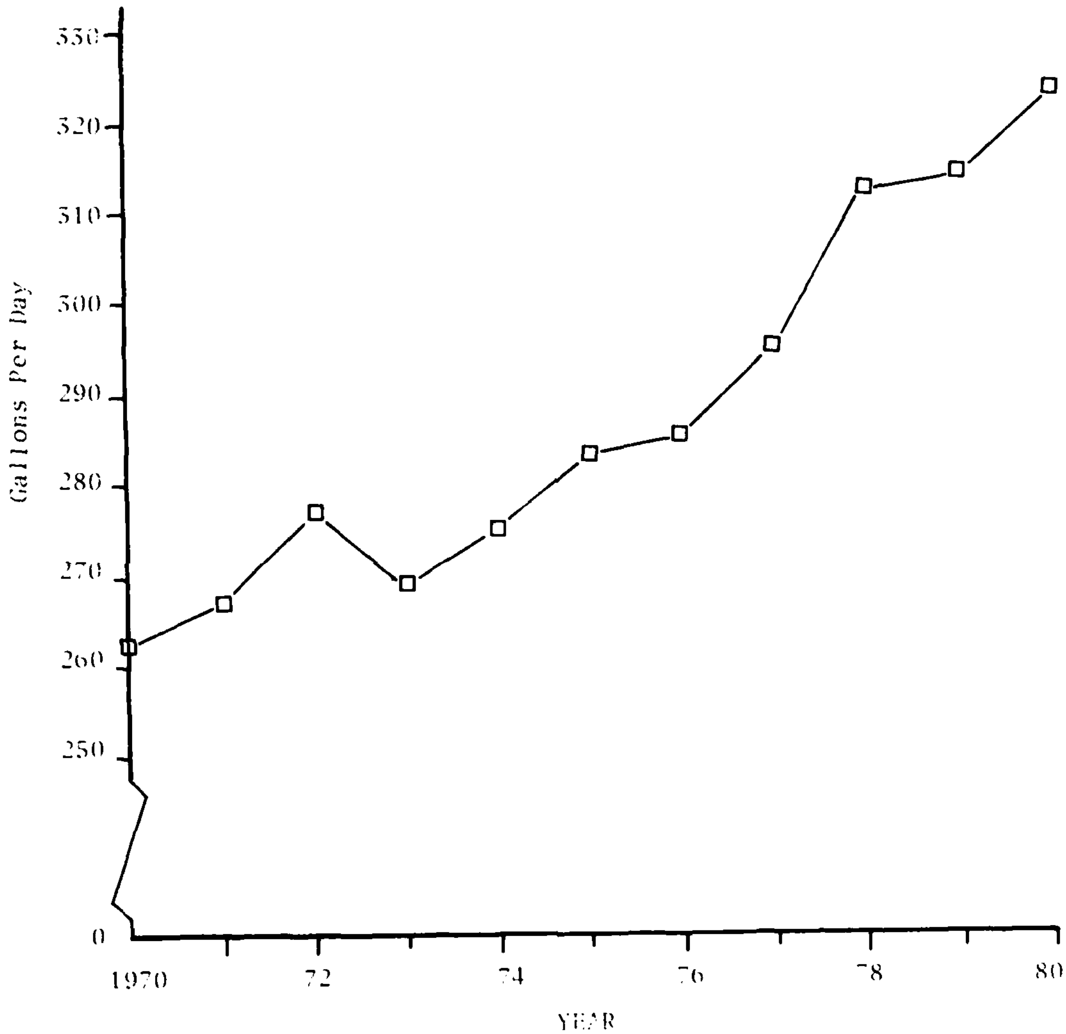

Figure VI-5. Industrial Water Use Per Employee, 1970-1980 negligible in the winter months. The non-seasonal model can be considered as a representation of those water uses which are not weather-related, such as indoor domestic use.

The final specification of the water use models will depend on the results of statistical analysis. Multicollinearity among the explanatory variables may force the exclusion of some of the intended parameters. Multicollinearity occurs when one or more of the explanatory variables are highly correlated with others. The effect of multicollinearity is to make it impossible to determine or isolate the effect of any one of the highly correlated variables on the dependent variable. In addition, the square of the multiple correlation coefficient (which measures the ratio of the sum of squares explained by the regression equation to the sum of squares unexplained by the regression equation) will fluctuate markedly as new variables are introduced into the equation.

In order to determine the final models, a number of multiple and bivariate regression analyses were performed. Total municipal water use was regressed against the seven explanatory variables. A second regression equation was developed where per capita municipal water use was expressed as a function of all variables except population. Both forms were tested for seasonal and non-seasonal municipal use.

Two main problems occurred in the development of these models. First, multicollinearity among the explanatory variables in the municipal use model was extremely high. Table VI-12 shows means and standard deviations for the variables, while Table VI-13 shows the correlation matrix. Very high correlations appear between moisture deficit and temperature and among the demographic variables of population, housing size and value of building permits. The number of connections is almost perfectly correlated with service area population.

The correlations of the explanatory variables with municipal water use agree with *a priori* expectations. All variables show a positive relationship with the dependent variable with the exception of rainfall and household size. Household size also has an inverse relationship with per capita use, which was expected. In addition, the number of connections, household size, value of building permits, and moisture deficit are strongly correlated with per capita water use.

A second statistical problem relates to the measurement basis of independent and dependent variables. In order to capture the seasonal variations in water use, it is possible to measure moisture deficit, temperature, rainfall and water use on a monthly or seasonal basis. In contrast, population, number of connections, household size and value of building permits are only available on an annual basis. This creates statistical problems with regard to the regression residuals. If the results of the regression analysis are to be meaningful, the residuals (the difference between the actual and the estimated dependent variable values for each case) must have the vollowing characteristics: a zero mean, a normal distribution, a constant variance, and no interdependence. Violation of any of these assumptions

Table VI-12. Municipal Water Use Variables

	Mean	Standard Deviation	Cases
WUSE	17,176.9636	3,421.0	11
TEMP	60.1364	17.3172	132
RAIN	3.7050	2.9079	132
MDEF	0.9538	2.6394	132
POPN	382,256.6364	10,875.193	11
CONN	124,101.2727	7,428.5174	11
HOUSE	2.6836	0.17569	11
BUILD	230.5727	112.600	11
PCAP	122.4818	20.91	11

WUSE: municipal water use (mg/year)

TEMP: average temperature (monthly) (°F)

RAIN: average maximum rainfall per month (inches/month)

MDEF: moisture deficit, average monthly value (inches/month)

POPN: average annual population of the service area

CONN: average number of connections

HOUSE: average number of residents per dwelling unit (persons/unit)

BUILD: average annual value of building permits ($1,000,000)

PCAP: per capita water use (gpcd)

Table VI-13. Correlation Matrix

Annual Variables

	WUSE	POPN	CONN	HOUSE	BUILD	PCAP
WUSE	1.0	0.97805	0.96418	-0.92466	0.84300	0.99966
POPN	0.97805	1.0	0.99488	-0.98135	0.81666	0.97377
CONN	0.96418	0.99488	1.0	-0.98486	0.80843	0.95843
HOUSE	-0.92466	-0.98135	-0.98486	1.0	-0.77699	-0.98138
BUILD	0.84300	0.81666	0.80843	-0.77699	1.0	0.83988
PCAP	0.99966	0.97377	0.95843	-0.91838	0.83988	1.0

Monthly Variables

	WUSE*	TEMP	RAIN	MDEF
WUSE*	1.0	0.48933	-0.24896	0.56768
TEMP	0.48933	1.0	0.2791	0.8166
RAIN	-0.14896	0.2791	1.0	-0.2025
MDEF	0.56768	0.8166	-0.2025	1.0

WUSE* = Fraction of monthly water use to annual water use.

Other variables as defined on Table VI-12.

may reduce the validity of the model. In addition, the measurement basis problem affects the ability of the independent variables to explain variations in the dependent variable (when the period of measurement differs).

The multicollinearity problem and the measurement basis problem prevent the development of the model originally intended. Multicollinearity prevents the inclusion of two or more highly correlated explanatory variables within a single equation and the measurement problem prevents the combination of monthly weather variables with annual demographic variables in the same model. Also, household size is excluded from further consideration due to the absence of credible local forecasts needed for its use in a forecasting model. Population per connection, a surrogate for household size, remains implicitly included in the form of variables POPN and CONN. With respect to building permit value, local experience indicates that construction activity is highly sensitive to national fluctuations in economic growth and interest rates. Past forecasts of the expected level of construction activity have been notably inaccurate.

As a result, two abbreviated models are tested, where municipal water use is expressed in alternative forms, each incorporating a single explanatory variable: the population of the service area and the number of connections. Bivariate regression equations are derived, based on historic data for the period 1970-80 (all variables are measured on an annual basis). The analysis yields the following results:

$$\mathrm{WUSE} = -100{,}430.05 + 0.307665\ \mathrm{POPN} \quad \text{(VI-4)}$$
$$R^2 = 0.95659$$

$$\mathrm{WUSE} = -37{,}927.27 + 0.44403\ \mathrm{CONN} \quad \text{(VI-5)}$$
$$R^2 = 0.92964.$$

In addition, summer variations in water use are represented by a regression equation where water use in the summer months is expressed as a function of moisture deficit. Moisture deficit was selected as the variable to explain the effect of climate on water use as it is correlated most highly with the dependent variable (Table VI-13). A bivariate regression was performed for both summer and winter months:

$$Y_s = 0.04634 + 0.00218\ \mathrm{MDEF}_s \quad \text{(VI-6)}$$
$$R^2 = 0.756$$

Where: MDEF_s = moisture deficit for summer months
Y_s = fraction of monthly water use to annual water use for all summer months.

$$Y_{ns} = 0.04297 + 0.00026\ \mathrm{MDEF}_W \quad \text{(VI-7)}$$
$$R^2 = 0.00725$$

Where: MDEF_W = moisture deficit for winter months
Y_{ns} = fraction of monthly water use to annual water use for all winter months.

The R^2 value for the summer equation is very high, indicating that much of the variation in summer water use is explained by moisture deficit. In contrast, the R^2 value for winter water use is very low. This follows *a priori* expectations that winter water use is not affected by weather variables and does in fact represent indoor or household demand.

Based on these results, further investigation explored the relationship of seasonal water use (from Table VI-8) to summer season moisture deficit. The final specification of the model incorporates seasonal and non-seasonal use into the forecast utilizing data presented in Table VI-14. Seasonal municipal water use was regressed on moisture deficit for the summer months which yields the following result:

$$FSEA = 0.096006 + 0.0014432\ MDEF_S \qquad (VI\text{-}8)$$
$$R^2 = 0.121417$$

Where: FSEA = fraction of total municipal water use which is seasonal.

The bivariate regressions for non-seasonal water use yield the following results:

$$Q_N = -92{,}021.396 + 0.28039\ POPN \qquad (VI\text{-}9)$$
$$R^2 = 0.95414$$

$$Q_N = -35{,}339.987 + 0.406924\ CONN \qquad (VI\text{-}10)$$
$$R^2 = 0.93765.$$

Industrial Water Use: Industrial use is represented by the following equation, based on data from 1970-1980 (Tables VI-6 and VI-11):

$$IWUSE = 5606.206 + 0.16448\ EMPLT \qquad (VI\text{-}11)$$
$$R^2 = 0.987$$

Where: IWUSE = industrial water use (mg/year)
EMPLT = industrial employment.

FORECAST

Future water use for the study area is forecast by use of equations VI-9 and VI-10 (alternative models for non-seasonal municipal use), VI-8 (for fraction seasonal municipal use), and VI-11 (for industrial use). These models require projections of future population, number of connections, summer season moisture deficits, and industrial employment. Other candidate variables were deleted in the course of model development. Population and number of connections are alternative explanatory variables because they are so highly correlated with each other as to make inclusion in the same model virtually meaningless.

Projections of number of connections and population are shown as Table VI-15. Number of connections was projected on the basis of 1970-1980 trends,

Table VI-14. Seasonal Water Use Variables, 1970-1980

	Total Municipal Water Use[1]	Seasonal Water Use[2]	FSEA[3]	$MDEF_s$[4]
1970	13,280.7	1,769.0	0.13320	16.74
1971	13,320.7	1,601.5	0.12023	16.24
1972	14,154.9	1,833.8	0.12955	15.63
1973	14,410.0	1,547.2	0.10737	6.05
1974	15,680.3	1,782.1	0.11365	9.31
1975	16,584.0	2,199.5	0.13263	15.74
1976	17,480.2	1,694.4	0.09693	15.69
1977	18,787.8	2,187.8	0.11645	17.51
1978	20,643.8	3,170.7	0.15359	20.85
1979	21,877.6	2,038.4	0.09317	15.19
1980	22,726.6	2,364.5	0.10404	20.63
		MEAN	0.118256	15.41636
		STANDARD DEVIATION	0.17997	4.34526

[1]Column 4, Table VI-6.

[2]Column 1, Table VI-8.

[3]Fraction of municipal water use which is seasonal (Col. 2/Col.1).

[4]$MDEF_s$ = Total moisture deficit for April through to November (inches/year) (Table VI-5)

Table VI-15. Projected Values of Explanatory Variables, 1985-2030

Year	Number of Connections	Population Per Connection	Service Area Population[1]
1985	146,652	2.79	409,159
1990	157,986	2.67	421,823
1995	170,195	2.54	432,295
2000	183,349	2.43	445,538
2010	212,784	2.21	470,253
2020	246,944	2.01	496,357
2030	286,589	1.83	524,458

[1]Population is estimated as the number of connections multiplied by population per connection.

as adjusted for expected future conditions. Population per connection also represents an extrapolation of 1970-1980 trends. The product of the two extrapolations yields a population projection, which was judged consistent with existing local and OBERS forecasts (available only for larger areas).

Summer season moisture deficit, which averaged 15.42 inches per year during the 1970-1980 period, is projected at its long-term average of approximately 10 inches per year. This provides a forecast of expected seasonal water use, although actual levels may be substantially higher or lower, according to weather conditions.

Since most industrial employment in the SMSA occurs within the study area, OBERS projections are used to develop projected industrial employment (Table VI-16).

In forecasting seasonal water use, the value of FSEA (fraction of water use which is seasonal) is first calculated. Using $MDEF_S = 10$, FSEA is equal to 0.110438 (from Equation VI-8). Since:

$$FSEA = \frac{Q_s}{Q_N + Q_S} \qquad \text{(VI-12)}$$

Then:

$$Q_s = \frac{FSEA * Q_N}{1 - FSEA} \qquad \text{(VI-13)}$$

Or:

$$Q_s = 0.124149\ Q_N \qquad \text{(VI-14)}$$

Using the projected values given on Table VI-15, and equations VI-9, VI-10, and VI-14, two alternative forecasts of municipal water use are prepared. These forecasts are shown on Table VI-17. Projections of industrial employment shown as Table VI-16 are combined with equation VI-11 to give the forecast of industrial water use shown on Table VI-18.

Analysis of Results

PROCEDURAL PROBLEMS

The forecasting procedure used in this study was complicated by unusually high historic growth in annual water use (see Table VI-6). Between 1970 and 1980, total water use increased at an average annual rate of 5.6 percent. However, the growth rate accelerated in the last half of the decade: 1970-1975 annual average growth rate is 4.5 percent and 1975-1980 annual average growth rate is 6.8 percent.

In addition, the annual average growth in water use exceeds the increases in both population and number of connections (Tables VI-9 and VI-10). The result is large increases in per capita and per connection water use.

Table VI-16. Projected Industrial Employment for the Service Area[1], 1985-2030

1985	135,784
1990	153,436
1995	172,250
2000	184,123
2010	202,100
2020	216,513
2030	226,471

[1]Derived from OBERS projections, 1980. Adjustments made to reflect only industries located in the service area.

Table VI-17. Forecast Municipal Water Use, 1985-2030

1) Water Use As a Function of Population

	Q_N[1]	Q_S[2]	Year	mgd
1985:	22,702.7	2,818.5	25,521.2	69.92
1990:	26,253.6	3,259.4	29,513.0	80.86
1995:	29,189.8	3,623.9	32,813.7	89.90
2000:	32,903.0	4,084.9	36,987.9	101.34
2010:	39,832.8	4,945.2	44,778.0	122.68
2020:	47,152.1	5,853.9	53,006.0	145.22
2030:	55,031.4	6,832.1	61,863.5	169.49

[1] Q_N = 92,021.396 + 0.28039 POPN

[2] Q_S = 0.124149 Q_N

2) Water Use As a Function of Connections

	Q_N[3]	Q_S[4]	Year	mgd
1985:	24,336.2	3,021.3	27,357.5	74.95
1990:	28,948.3	3,593.9	32,542.2	89.16
1995:	33,916.4	4,210.7	38,127.1	104.5
2000:	39,269.1	4,875.2	44,144.3	120.9
2010:	51,246.9	6,362.3	57,609.2	157.8
2020:	65,147.5	8,088.0	73,235.5	200.6
2030:	81,280.0	10,090.8	91,370.8	250.3

[3] Q_N = -35,339.987 + 0.406924 CONN

[4] Q_S = 0.124149 Q_N

Table VI-18. Projected Industrial Water Use for the Study Area, 1985-2030

Year	Industrial Water Use	
	Year	mgd
1985	16,728	45.83
1990	19,631	53.78
1995	22,726	62.26
2000	24,678	67.61
2010	27,635	75.71
2020	30,006	82.21
2030	31,644	86.70

The historic pattern of water use is of primary importance, as the forecasting approach selected attempts to estimate future water use on the basis of past consumption trends. Very high historic growth rates will cause very high forecast values for water use when time extrapolation is used. In this study, it is considered unrealistic to assume that the extraordinarily high growth rates in 1970-1980 will continue to the year 2030. For this reason, the projected number of connections is extrapolated at a lower growth rate than the annual average for 1970-1980. It was decided not to assume that the number of connections would increase at a decreasing rate but rather to keep the annual rate of increase constant over the planning period. This assumption implies continuing growth, although at a lower than historic level and avoids additional judgments unsupported by available information. Industrial employment, however, is assigned a curvilinear trend, based on OBERS projections.

Investigations were made to ascertain the reasons for the high growth rates observed during the 1970-1980 period. Of crucial importance is whether or not the large increase in water use is evidence of some continuing process or reflects a temporary abnormality. Conversations with representatives of the water utility and government planning agencies suggest the likelihood of continuing increases in the future. The following reasons were given for the unusually high rates of increase:

- the city is undergoing economic growth especially in the commercial sector (the city has the highest percentage of commercial and industrial use in the state).
- the city is host to many conventions and this would contribute to higher than average levels of water use not reflected in the population figures.
- the city is taking on more of a regional role in the state and is growing faster as an employment center than population figures suggest.

Despite these indications that past increases in water use for the city may continue, a number of additional factors need to be considered. For example, the big increase in per capita water use between 1977 and 1978 is not fully explained by increased water sales; 50-75 percent of the increase is attributed to unaccounted water. Also, future constraints on the supply of water may mean that water intake per person will have to be reduced in the late 1980's unless additional sources of supply are found.

Where only Level 2 data are available, the problem remains one of forecasting water use on the basis of historic data and a limited set of explanatory variables, covering a period when unusually high growth rates were experienced. While it appears unlikely that such growth rates will continue on into the indefinite future, a departure from simple extrapolation requires the forecaster to make subjective judgments about the expected future growth rate of explanatory variables. To make such assumptions, the forecaster must attempt to gain a deeper understanding of the urban development process, which may require much more detailed information than is available in this study.

The most difficult problems in application include those related to the delineation of service area boundaries, the changing service area population over time, and the projection of explanatory variables. The service area population was estimated on the basis of available information and explanatory variables for municipal water use were extrapolated from historical data in the absence of good quality forecasts from planning and/or government agencies.

The overall objective of this study has been to estimate future water use for a medium-sized city on the basis of past consumption trends and a limited set of possible explanatory variables. The basic assumption of this approach is that trends experienced in the past will continue into the future. As additional information is obtained, the results can be modified to account for other factors which may be found to influence water use.

WITH- VS. WITHOUT-PROJECT CONDITIONS

The forecast described here is not intended for use in evaluating federally-planned water resource projects. No "with-project" condition exists, therefore. The results presented can be considered a "without-project" forecast.

Had a federally-planned project been under consideration, however, the forecasting method chosen provides little scope for investigating project impacts on future water use. The explanatory variables most likely to be affected by a project, such as price, are not included in the water use models, so their effect cannot be described in quantitative terms. Subjective estimates of the effect of the project on the development and growth of the community might result in revised projections of population, number of connections, or industrial employment, but such revisions are not likely to be reliable. In general, project planning requires the use of forecasting methods which are more detailed than the single coefficient methods applied here.

COMPARISON WITH OTHER FORECASTS

The results obtained in the Level 2 study are summarized on Table VI-19, in addition to the results of three previous studies. Study 1 was conducted by private consultants in 1982 and refers to the same study area as that for the Example B study. Studies 2 and 3 were conducted by a local government agency, Study 2 being undertaken in 1978 and Study 3 in 1981.

For the Example B study, water use expressed as a function of population [number of connections times population per connection] plus a seasonal component provides a lower bound forecast of municipal water use [Table VI-19]. The result is considerably below the Study 1 forecast for the same service area. Study 1 utilized a per capita method where the population projection was obtained by multiplying a connection forecast by 3.0 person per connection. The per capita water use coefficient was extrapolated from historic values. These results are similar to or less than the upper bound levels of municipal water use forecast in the Example B study, where water use is

Table VI-19. Comparison With Other Forecasts (Ave. Day Water Use in mgd)

Year	EXAMPLE B STUDY (utility service area, as adjusted) (1982)			STUDY NO. 1 (utility service area) (1982)		STUDY NO. 2 (urban area)* (1978)			STUDY NO. 3 (urban area)* (1981)	
	Municipal Low	Municipal High	Industrial	Municipal	Industrial	Municipal Low	Municipal High	Industrial	Municipal & Industrial Low	Municipal & Industrial High
1980						80.1	86.8	27.2		
1985	69.9	75.0	45.8	81.9	28.5					
1990	80.9	89.2	53.8	94.0	30.5	94.6	113.3	31.6	130.4	151.3
1995	89.9	104.5	62.3	106.6	32.7					
2000	101.3	120.9	67.6	120.9	35.0	106.3	134.8	35.4	165.3	198.1
2010	122.7	157.8	75.7	144.5	40.1	111.5		39.5	186.9	212.0
2020	145.2	200.6	82.2	172.8	46.0	116.9		47.4	212.6	230.0
2030	169.5	250.3	86.7	206.5	62.8	122.7		55.7	235.4	252.4

*urban area closely approximates SMSA

expressed as a function of the number of connections and a seasonal component.

Forecast industrial water use is substantially higher for the Example B study than for Study 1. This is apparently due to differences in the definition of the industrial water use sector. Industrial water use for Study 1 comprises water use by the 22 largest industrial water users of the city. These firms, however, have represented only 68 percent of total industrial water use in recent years. The study described in this report considers total industrial water use for the study area.

Studies 2 and 3 predict water use for the urban area, a region which roughly approximates the SMSA. Municipal water use forecasts were made by multiplying projected per capita municipal water use by the projected population of the urban area. In Study 2, the municipal projections made through the year 2000 closely approximate those made by Study 1 and the upper bound for Example B, even though Study 2 addressed a much larger area. After year 2000, the Study 2 projections fall below those of the other studies, as per capita water use is assumed constant at 173 gpcd. Overall, there is a large discrepancy between the results of Study 2 and the other studies. This can be seen by recalling that the Example B study area should account for only about 70 percent of water use in the urban area. One major reason for this discrepancy is that the projections made of urban area population for Study 2 underestimated actual growth rates. For example, the population projections made for 1985 were exceeded by 1980.

As a result, a revised forecast for urban water use was made in 1981 (Study 3). The assumptions made in 1978 were modified to accommodate higher projected growth rates. These results are still substantially below results of other studies. This is due to the use of projected per capita use rates based on a state-wide average, well below the experience of the study area.

The industrial water use forecast in Study 2 closely approximates the results of Study 1. Industrial water use was calculated by applying water use per employee data to industrial employment estimates for the urban area. The water use per employee coefficients were also combined with projected changes in recirculation rates and projected changes in employee productivity.

VII. EXAMPLE C — LEVEL 3 DATA

Background and Approach

STUDY AREA

Example C is a water use forecast for a medium-sized port city in a mid-Atlantic state. The city comprises the core of a metropolitan area which includes several additional urban centers. The SMSA is characterized by major port-related and military activities, as well as heavy industry and tourism. The climate is warm temperate with hot, humid summers and mild winters. The city, which includes approximately one-third of the SMSA population, is served by a municipally-owned water utility. The utility maintains its own water sources, and supplies some water through bulk meters to areas outside the city limits. No retail customers are located outside the city.

The study area is defined by the corporate limits of the city, corresponding to the retail service area of the water utility. The study area consists, therefore, of a mature, port-oriented urban area with a substantial military population. Only limited tracts of undeveloped land are available within the study area, so that significant future population growth can only occur at higher densities than at present.

In 1975, approximately 30 percent of the land area of the city was in residential use, of which more than 70 percent was classified as low density. Commercial and institutional (including military) use occupied 25 percent of available land while industrial and public uses covered 22 percent. Nearly 9 percent of the land within the city was vacant and the remainder was occupied by lakes and other water surfaces. Agriculture accounted for a negligible fraction. By the year 2000, residential land use is expected to increase slightly as the result of a small decrease in high density use and a more than offsetting increase in low density use. Small expansions are also projected for the commercial and industrial sectors. The total area of 40,528.8 acres is not expected to change during this period (Table VII-1).

FORECAST REQUIREMENTS

The forecast described here is performed as part of an overall assessment of the adequacy of existing water sources in the region. In order to be consistent with forecasts being prepared for other water utility service areas in the SMSA, the base year is 1975, and forecasts are required at ten year intervals through the year 2030. Only average day water use is required, as facility design is not contemplated.

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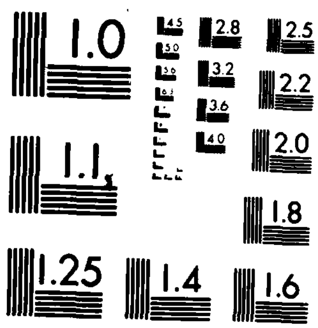

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE VII-1. Study Area Land Use Projections, 1970-2000 (acres)

	1970	1975	1980	1990	2000
Low Density Residential	8,468	8,572	8,676	8,713	8,726
High Density Residential	3,505	3,499	3,433	3,466	3,470
Commercial/Institutional	10,316	10,551	10,786	10,929	11,102
Industry/Streets	8,760	8,791	8,823	8,848	8,870
Agriculture	9	10	7	7	6
Water	5,567	5,567	5,567	5,567	5,567
Vacant	3,905	3,539	3,263	3,000	2,789
Total	40,529	40,529	40,529	40,529	40,529

The subsequent planning process, in addition to reviewing supply adequacy, will address questions regarding inter-jurisdictional transfers of water and water conservation programs. Because of the possibility of inter-jurisdictional transfers, each water utility service area is separately forecast, as in this example. Because water conservation measures may be later evaluated, each forecast should be disaggregated by user sector.

CHOICE OF FORECASTING METHOD

Both the planning context (later evaluation of water conservation) and the characteristics of the study area (large non-residential sectors, limited residential growth) suggest the use of a sectorally disaggregate forecasting method. Preliminary assessment of data availability, however, indicates that no sectorally disaggregate water use data are available, and that limited data on explanatory variables can be readily obtained.

Accordingly, small samples were drawn from each major water use sector (see Section IV), and billing record analyses and telephone interviews were conducted to obtain water use and explanatory variable data. The results of this survey were augmented by other data available from public sources to obtain a data base sufficient for a disaggregate multi-variate forecasting approach, with coefficients based on cross-sectional analysis within the study area. Investigation of relationships among the data, however, ultimately led to the adoption of unit use coefficient models for each of six user sectors.

Data Collection

DEMOGRAPHIC AND HOUSING DATA

Although this example relies on cross sectional data for estimating water use model coefficients, some time series data are available for examination as background material and for setting the forecast in context. Population is an example of such data, and its historical development in the study area can be summarized as having increased from less than 10,000 in the early 1800's to a maximum of approximately 310,000 in the 1960's or 1970's (see Table VII-2). Although there is some ambiguity regarding the treatment of military personnel in recent census counts, the 1980 population shows a significant decline from that of 1970.

It is a reasonable hypothesis that the population of a mature city within a larger urban area would display signs of stabilization or even loss to the surrounding area as regional growth continues. Population data for several other older central cities on the East Coast exhibit a similar decline in numbers during the past decade as shown on Table VII-3. Another

TABLE VII-2. Study Area Population, 1790-1980

Year	Population	Year	Population	Year	Population
1790	2,959	1860	14,620	1930	129,710
1800	6,926	1870	19,229	1940	144,332
1810	9,193	1880	21,966	1950	213,513
1820	8,478	1890	34,871	1960	304,869
1830	9,814	1900	46,624	1970	307,951
1840	10,920	1910	67,452	1980	266,979
1850	14,320	1920	115,770		

Source: U. S. Census of Population

Table VII-3. Central City Population Change, 1960-1980

	1960 population	% increase	1970 population	% increase	1980 population
Study Area	305,000	+1.0	308,000	-13.4	267,000
City A	764,000	-1.0	757,000	-15.6	638,000
City B	939,000	-3.5	905,000	-13.1	787,000
City C	2,003,000	-2.6	1,950,000	-13.4	1,688,000
City D	7,782,000	+1.5	7,896,000	-11.5	7,072,000
City E	697,000	-8.1	641,000	-12.2	563,000

Source: U. S. Census Reports

important influence on population growth in the past appears to have been military activity, which supports a substantial fraction of employment and commercial activity in the city. Relatively large additions were made to the population in the period 1910-1920 and 1940-1960. These apparent underlying phenomena would argue against the use of time series extrapolation for projecting population figures.

No existing independent forecast of population accounts for the abrupt change in trend indicated by the 1980 census. Therefore, as a prerequisite to the water use forecast, a projection of population must be derived. Based on the experience of other East Coast cities in similar circumstances, population for the study area is projected to decrease in each future decade at a rate equal to one-half the percentage decrease of the previous decade. This assumption has the effect of continuing the recently observed decline for a time while population stabilizes in the longer term. In the absence of a detailed explanation of the recent decrease, this type of forecast is thought to be more applicable for the type of area under consideration than more complex techniques; it is certainly more applicable than existing forecasts, which show continued growth. The resulting population projections are given in Table VII-4 and plotted in Figure VII-1.

Data relevant to calculating average household size are readily available back to 1930, when the average was 4.78 persons per household (pphh). Since then average household size has decreased monotonically to approximately 2.8 pphh in 1980. Historic data and projections for the future are given in Table VII-4 and plotted in Figure VII-2. As with the population projection, a stabilizing trend is assumed and is derived by reducing the difference in household size between successive decades until it is constant after the year 2010.

For the purposes of this forecast, the residential sector is divided into single family residences (SFR's) and multifamily residences (MFR's). U. S. Census of Housing figures show an increase in the number of dwelling units over the last four decades, with the largest increase during the 1950's. The proportion of SFR's grew from 43 percent in 1940 to approximately 50 percent in 1960 and appears to have stabilized or declined slightly since then.

Given the projection of overall average household size and population in private households, the number of dwelling units and resident population in both SFR's and MFR's are derived for use in the residential forecasting model. These data are developed in such a way that, for each decade, they are internally consistent while at the same time conforming to the previously discussed projections of average household size and residential population (Table VII-4).

WATER USE DATA

Residential

Consistent with the housing unit projection, the residential water use

Table VII-4. Study Area Civilian Population and Household Data 1940-2030

Year	Total Population	Population Private HH	Number of SFR's	Number of MFR's	Total Dwelling Units or HH's	Combined HH Size
1940	144,332	135,445	16,581	20,822	37,403	3.62
1950	213,513	176,352	20,452	33,526	53,978	3.30
1960	304,869	267,394	44,707	37,123	81,830	3.27
1970	307,951	263,283	45,678	44,361	90,039	2.92
1975	285,000	251,620	44,640	43,360	88,000	2.86
1980	266,979	244,850	44,100*	43,000*	87,100*	2.81
1990	249,000	226,870	42,200	41,200	83,400	2.72
2000	241,000	218,870	41,500	40,500	82,000	2.67
2010	237,000	214,870	41,200	40,200	81,400	2.64
2020	235,000	212,870	40,800	39,800	80,600	2.64
2030	234,000	211,870	40,600	39,700	80,300	2.64

*1980 undisaggregated figure of 94,871 only data available, which is believed to include approximately 7,771 military households.

Sources: 1940-1970 U. S. Census Reports
1975 Adjusted interpolated data
1980-2030 Projected data (except 1980 Total Population)

Where: HH = Household Unit
SFR = Single Family Residence
MFR = Multi-Family Residence

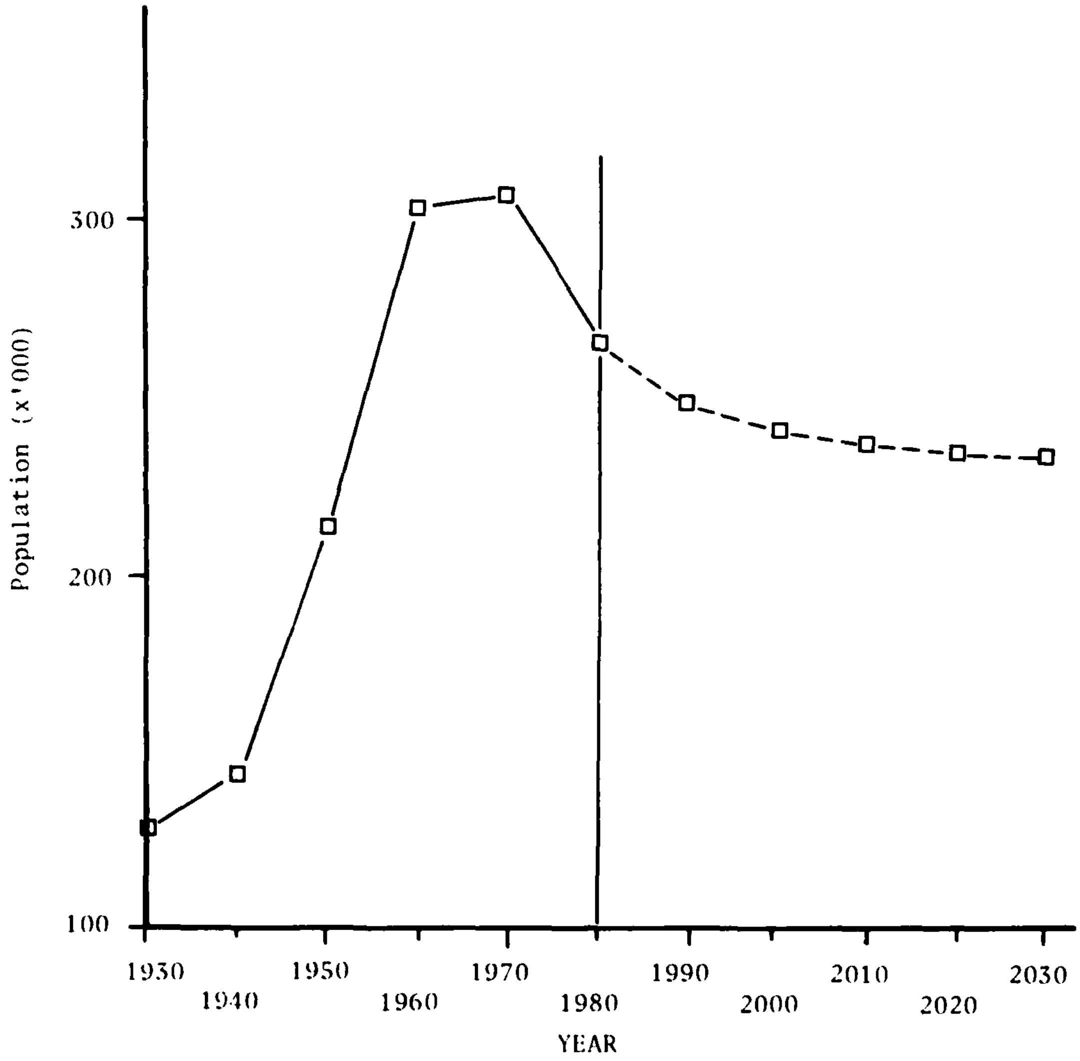

Figure VII-1. Study Area Civilian Population Data

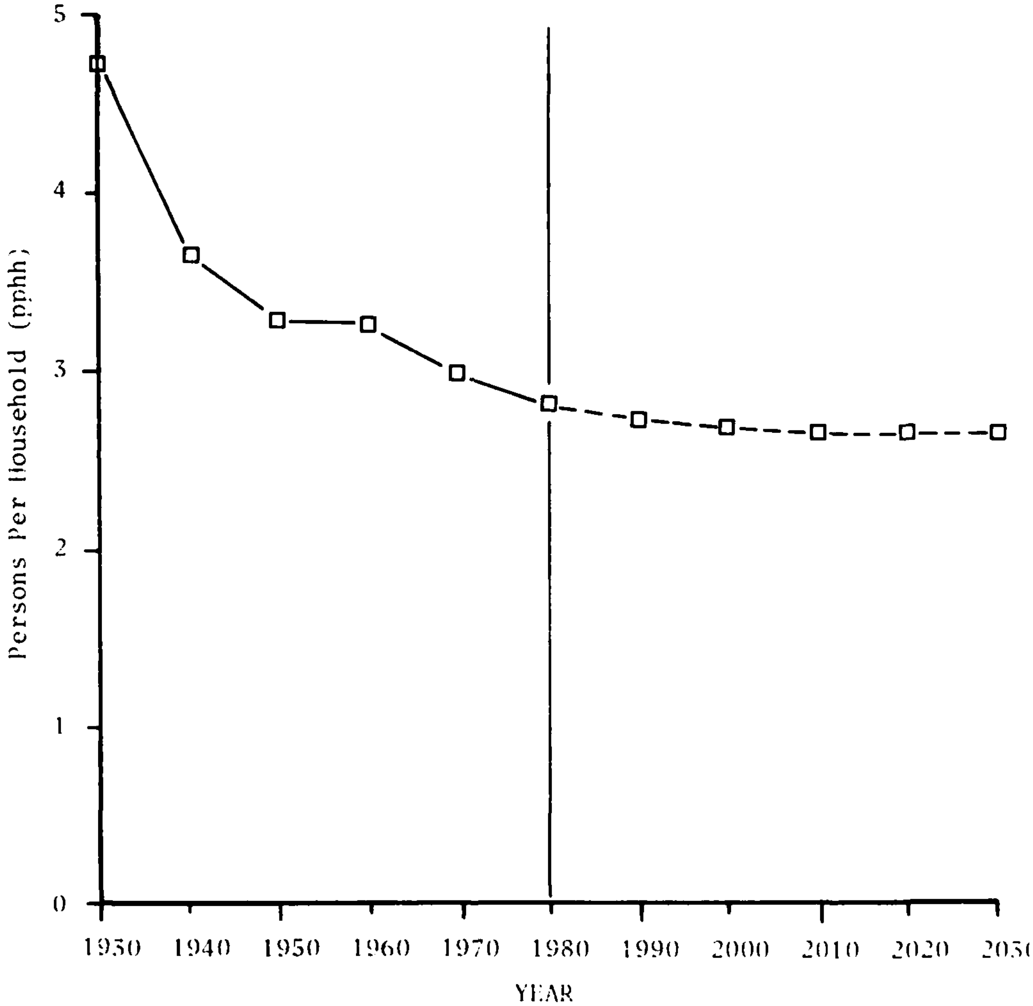

Figure VII-2. Study Area Household Size (pphh) category is divided into two sub-sectors: single family residences (SFR) and multifamily residences (MFR). A sample of each sub-sector was identified, and various information collected by billing record analysis and telephone interview. The information, for the calendar year 1975, included: water use, household size, number of bathrooms, assessed value of residence and lot for SFR's, and monthly rent and number of apartments per meter for MFR's. The data obtained are summarized and analyzed in the discussion of forecast models, below.

Commercial/Industrial

During the 1975 base year, 21 percent of total water consumption is attributed to commercial and industrial users. A sample of both large and small firms provides the information on which to base the data, and two subsectors are defined. Meter records for all firms using more than 50,000 gallons per day (gpd) were examined and totaled. Manufacturing firms (one-digit 2 and 3) were separated from the rest and treated as a distinct subsector (industries with large process water requirements). Together, these firms accounted for 1.18 mgd in the base year (Table VII-5).

The other commercial/industrial subsector is composed of the remaining manufacturing firms (using less than 50,000 gpd) and all other non-residential (except military) users. The consumption attributed to this broader subsector is 7.76 mgd in the base year.

Water use in both subsectors is projected to change proportionate to changes in future employment within the example city. A forecast of future employment levels disaggregated by SIC was provided by a regional planning agency and is summarized in Table VII-6.

The institutional sector usually includes hospitals and schools as well as military establishments. However, because military usage so heavily dominates the sector in this example, all other institutional water use is included in the remainder commercial/industrial subsector.

No detailed metering information is available for water use on military bases, therefore any disaggregation is hypothetical. For the purposes of this forecast, it is assumed that residents of the military base use water at a rate comparable to that of residents of civilian multi-family units. This equivalence is made plausible by the fact that neither residential category pays directly for water use: in one case it may be included in rent and in the other it can be considered free. The remainder of consumption is attributed to employment-related uses, although some uses are obviously recreational.

For the 1975 base year, the following disaggregation of military water use is made:

14,630 residents @ 68 gpcd	0.99 mgd
76,100 employees @ 81 gped	6.19
Total	7.18 mgd

Table VII-5. Manufacturing Firms (SIC 2 and 3) Using More Than Approximately 50,000 GPD, 1975

Water User		1975 Water Use (gpd)
Firm A		430,860
Firm B		113,520
Firm C		63,750
Firm D		223,980
Firm E		48,850
Firm F		131,510
Firm G		64,130
Firm H		100,300
	Total	1,176,900
		1.18 mgd

Table VII-6. Study Area Employment Projections, 1975-2030 (thousands)

	1975	1980	1990	2000	2010	2020	2030
Total Private Sector	100.85	105.20	113.90	122.18	130.05	137.51	144.55
Total Manufacturing (SIC 2 & 3)	14.75	14.90	15.20	15.48	15.75	16.01	16.25
Remainder	86.10	90.30	98.70	106.70	114.30	121.50	128.30

Source: Regional Planning Agency

Where: gpcd = gallons per capita per day
gped = gallons per employee per day

According to military sources, the residential population is expected to remain constant through the forecast period, and employment is expected to rise to 103,200.

Public and Unaccounted

The utility has indicated its commitment to a program of meter renewals and leak detection that is expected to halve the rate of unaccounted water use by the year 1990. This program, if it remains active, is estimated to reduce the unaccounted water from 24.5 percent (10.6 mgd) in 1975 to 12.3 percent in 1990 and beyond.

OTHER INFORMATION

Conservation Measures

In addition to reductions in unaccounted water usage, a plumbing code has been adopted which limits the flow of residential showers and faucets to no more than 3 gallons per minute (gpm). The implementation of this code is expected to bring about an eventual reduction of 9 gpcd for all private residential consumers. National housing data indicate that dwelling units are replaced at intervals of approximately 50 and 75 years, and it is assumed that plumbing fixtures are replaced through remodelling at intervals of less than 50 years. Thus, for the purposes of this example, it is assumed that all private residents will be using approved fixtures within 50 years of the 1975 base year. This is accomplished in the forecast by an increase of 10 percent of the housing stock having new fixtures for each successive five years to 2025.

Water Resources and Demands

The resources upon which the city relies for its supply are an amalgam of surface reservoirs, wells and river intakes. From these sources the city also provides partial or total supplies (under contract) to a separate military base and two adjacent communities, not included in the study area. Both of the external communities are pursuing water resource developments of their own which will reduce their reliance on the city's system. The total safe yield is estimated to be 80 mgd, and the total capacity of the city's two water treatment plants is nominally 90 mgd.

The total demands during the period 1972 to 1975 ranged from 60 mgd to 65 mgd, of which the city used 44 mgd to 46 mgd or approximately 70 percent. The average daily demand for the city in the 1975 base year was 43.29 mgd, which on the basis of the sample survey can be disaggregated as shown in Table VII-7. No seasonal or year to year comparisons of sectoral water use

Table VII-7. Disaggregate Water Use, 1975

Sector		Source of Data
Residential		
Single Family	10.40 mgd	Adjusted sample information
Multi Family	6.17	Adjusted sample information
Manufacturing Industry		
$\gtrsim$ 50,000 gpd	1.18	Adjusted sample information
Commercial and		
Other Industry	7.76	Residual
Military	7.18	Utility records
Unaccounted	10.60	Utility records
Total Demand	43.29 mgd	Utility records

can be made when the data consist of a base year cross sectional sample as in this example. Thus, there is no clear way of knowing the effect of changes in weather and economic conditions.

Water Supply System

As previously stated, two treatment works supply all the water to the study area plus some of the requirements of adjacent communities. No water is imported into the study area from other systems, and all water must be pumped into distribution due to the low elevation of sources. All residents within the city are served by the utility and all customers are metered. Water bills are rendered on a quarterly or bi-monthly staggered cycle. Supplies are provided to the adjacent communities on a wholesale basis and each has its own billing and revenue collection arrangements. That water which is supplied to external customers is metered and has been excluded from this analysis which considers only water used within the study area.

Water Use Forecast

SECTORAL FORECASTS

Residential

Analysis of the data obtained in the sample survey was carried out by the use of least squares linear regression between water use as the dependent variable and all descriptive variables singly and in combination. The best regressions found statistically significant at the 5 percent level all involve no more than one independent variable. Among those, the following equations are suitable for use as forecasting models:

Single Family Residences

$$QRES = 20.65 + \underset{(9.60)}{59.01}\ HHSIZE \qquad \text{(VII-1)}$$
$$\bar{R}^2 = 0.49,\ SEE = 82.8$$

Multi-Family Residences

$$QPC = 140.20 - \underset{(12.22)}{34.50}\ HHSIZE \qquad \text{(VII-2)}$$
$$\bar{R}^2 = 0.30,\ SEE = 30.2$$

Where: QRES = consumption per residence, gpd
HHSIZE = persons per household
QPC = consumption per capita, gpcd

( ) = standard error of coefficient
$\bar{R}^2$ = fraction explained variance, adjusted
SEE = standard error of estimate of the regression

These results can be adjusted for the eventual effect of new plumbing fixtures by deducting 9.0 gpcd:

Single Family Residences

$$QRES = 20.65 + 50.01\ HHSIZE \qquad (VII\text{-}3)$$

Multi-Family Residences

$$QPC = 131.20 - 34.50\ HHSIZE \qquad (VII\text{-}4)$$

Application of these equations to the projected data discussed in the previous section provides the residential water use forecast given in Table VII-8.

Commercial/Industrial

Water use of manufacturing firms in SIC Codes 2 and 3 requiring more than approximately 50,000 gpd is forecast separately from smaller manufacturers which are combined with all other commerce and industry. The results of forecasts for both subsectors are based upon the historic and projected data discussed in the last section (Table VII-6) and are presented in Table VII-9. Water use is projected to change proportionately with corresponding subsector employment.

Institutional (Military)

The forecast is based on projections of two descriptive variables provided by military sources: resident military personnel (including dependents) and military employment. The per capita residential water use is assumed to be equivalent to that of the MFR sub-sector and the remainder of consumption is derived by assuming unit use remains constant at base year levels throughout the forecast period. The results for the sector are given in Table VII-10.

Public and Unaccounted

The forecast of public and unaccounted water use is based on the intentions of the utility to reduce the 1975 rate of unaccounted water by one-half before 1990. This strategy produces the following percentages of unaccounted water during the forecast period:

Year:	1975	1980	1990-2030
Percent Unaccounted:	24.5%	20.4%	12.3%

Table VII-8. Residential Water Use Forecast, 1975-2030

	1975	1980	1990	2000	2010	2020	2030
Total Private HH Population	251,620	244,850	226,870	218,870	214,870	212,870	211,870
Single Family Population	160,564	155,850	144,400	139,310	136,760	135,490	134,850
Households	44,640	44,100	42,200	41,500	41,200	40,800	40,600
Household Size	3.60	3.53	3.42	3.36	3.32	3.32	3.32
HH's Old Fixtures	44,640	39,690	29,540	20,750	12,360	4,080	-0-
Water Use (mgd)	10.40	9.09	6.57	4.54	2.68	0.88	-0-
HH's New Fixtures	-0-	4,410	12,660	20,750	28,840	36,720	40,600
Water Use (mgd)	-0-	0.87	2.43	3.92	5.38	6.86	7.58
Total SFR Use (mgd)	10.40	9.96	9.00	8.46	8.06	7.74	7.58
Multi-Family Population	91,060	89,000	82,470	79,560	78,110	77,380	77,020
Households	43,360	43,000	41,200	40,500	40,200	39,800	39,700
Household Size	2.10	2.07	2.00	1.96	1.94	1.94	1.94
HH's Old Fixtures	43,360	38,700	28,840	20,250	12,060	3,980	-0-
Population Old Fixtures	91,060	80,109	57,730	39,780	23,430	7,740	-0-
Water Use (mgd)	6.17	5.51	4.11	2.89	1.72	0.57	-0-
HH's New Fixtures	-0-	4,300	12,360	20,250	28,140	35,820	39,700
Population New Fixtures	-0-	8,900	24,740	39,780	54,680	69,640	77,020
Water Use (mgd)	-0-	0.53	1.54	2.53	3.51	4.48	4.95
Total MFR Use (mgd)	6.17	6.04	5.65	5.42	5.23	5.05	4.95
Residential Use (mgd)	16.57	16.00	14.65	13.88	13.29	12.79	12.53

Table VII-9. Commercial/Industrial Water Use Forecast, 1975-2030

	1975	1980	1990	2000	2010	2020	2030
Manufacturing							
Employment, (1,000)	14.75	14.90	15.20	15.48	15.75	16.01	16.25
Ratio to Base Year	1.00	1.01	1.03	1.05	1.07	1.09	1.10
Water Use, mgd	1.18	1.19	1.22	1.24	1.26	1.28	1.30
Remainder							
Employment, (1,000)	86.1	90.3	98.7	106.7	114.3	121.5	128.3
Ratio to Base Year	1.00	1.05	1.15	1.24	1.33	1.41	1.49
Water Use, mgd	7.76	8.14	8.90	9.62	10.30	10.05	11.56

Where: Water Use = Ratio x 1975 water use.

Remainder Employment = All non-manufacturing employment except military.

Table VII-10. Military Water Use Forecast, 1975-2030

	1975	1980	1990	2000	2010	2020	2030
Military Population	14,630	14,630	14,630	14,630	14,630	14,630	14,630
Unit Water Use (gpcd)	68	68	68	68	67	65	64
Residential Water Use (mgd)	0.99	0.99	0.99	0.99	0.98	0.95	0.94
Military Employment	76,100	85,300	93,700	96,000	98,400	100,800	103,200
Unit Water Use (gped)	81	81	81	81	81	81	81
Other Water Use (mgd)	6.19	6.91	7.59	7.78	7.97	8.16	8.36
Total Water Use (mgd)	7.18	7.90	8.58	8.77	8.95	9.11	9.30

COMBINED FORECAST

The combined forecast for the study area is presented in Table VII-11 and represents the total aggregated results of each of the separately projected sectors for each of the chosen intermediate years.

Analysis of Results

PROCEDURAL PROBLEMS

When a forecast is based on cross-sectional data, it is generally assumed that functional relationships existing among variables in the base year continue unchanged throughout the period of the forecast. This assumption is relaxed somewhat in this example where conservation measures in the residential sector explicitly change the relationship between water use and the relevant independent variables.

Due to the recent release of 1980 census data which show a marked departure from past trends in population growth, the available independent projection of population for the study area did not appear to be appropriate. The latest OBERS projections of population and economic conditions pre-dated the results of the 1980 census and were available only for the relatively large SMSA. Consequently, the projection used in the forecast may be somewhat arbitrary in its attempt to account for the shifting trend over the forecast period. However, the declining trend in household size has been consistent over recent decades, and the pattern of its extension is less arbitrary.

Although the information derived from sampling in the residential and commercial/industrial sectors did not produce significant multi-variate regressions as initially anticipated, the single function relationships that were derived are consistent with those established in more detailed studies.

The accurate forecast of military consumption is made difficult by the absence of any useful sectoral data, and by an arbitrary but official projection of constant residential population.

The estimate of public and unaccounted water use is based on the accumulated inaccuracies of many meters and the combined effects of countless undetected leaks. Thus, the forecast of decreasing unaccounted use may be influenced more by good intentions than practical realities.

Specific difficulties in producing the forecast fell into three categories. The first includes difficulties in obtaining a good sample of water use and descriptive data on which to base functional relationships. Water use data were readily available but the results of sampling for the other variables produced only the simplest relationships. Second, good projections of the relevant descriptive variables were not always available. Those for population did not appear to account for the reduction between 1970-1980.

Table VII-11. Combined Forecast, 1975-2030 (mgd)

	1975	1980	1990	2000	2010	2020	2030
Single Family	10.40	9.96	9.00	8.46	8.06	7.74	7.58
Multi Family	6.17	6.04	5.65	5.42	5.23	5.05	4.95
Manuf. Ind.	1.18	1.19	1.22	1.24	1.26	1.28	1.30
Remainder Ind.	7.76	8.14	8.90	9.62	10.30	10.95	11.56
Military	7.18	7.90	8.58	8.77	8.95	9.11	9.30
Unaccounted	10.60	8.52	4.68	4.70	4.82	4.79	4.87
Total	43.29	41.75	38.03	38.21	39.16	38.92	39.56

The third major area of difficulty was in producing an internally consistent forecast, especially in the residential sector where projections of household size, number of dwelling units and population for SFR's, MFR's and total all had to be reconciled at ten year intervals throughout the forecast period.

WITH- VS. WITHOUT-PROJECT CONDITIONS

Since no project plan is contemplated as a result of this forecast, no with-project condition need be evaluated. However, if a project were under consideration, the forecast method chosen offers little assistance in identifying the effects of the project on water use. Due to the nature of the service area, and the surrounding topography, any new water supply facility would likely be remote from present and future water users. Project-induced effects may be limited, therefore, to the impact of lower future prices on water use. Since price is not included as an explanatory variable, differences in future price levels can only be reflected by changes in model coefficients (a similar method is used to incorporate the effect of the existing water conservation measures). Such adjustments may be unreliable, and should be performed with caution.

APPLICATION OF RESULTS

A forecast produced with Level 3 Data is sufficiently disaggregated to capture most of the characteristic trends in the several major water use sectors. As such, it can be used as the basis for planning and design of all but the largest and most critical projects. The data in this example provides a direct forecast of only average day water use, although seasonal or maximum monthly and daily projections might be derived by a similar approach.

COMPARISON WITH OTHER FORECASTS

One recent forecast which employs a similar disaggregation of water use sectors is available for comparison. Results are given in Table VII-12 for comparison with this example. The Example C forecast for the year 2030 is lower than in the other study for the residential, manufacturing and unaccounted sectors. Military and remainder commercial/industrial water use is forecast to be higher in the example than in the other study. The trends in all sectors are similar between the two forecasts except that of the remainder commercial/industrial sector. In the previous study this sector peaks at 7.93 mgd in the year 2000 then declines to near the base year value by 2030, while in this example it continues to increase to the end of the planning period.

Table VII-12. Comparison with Other Forecast (mgd)

	2030	
	Example C	Other Study
Residential	12.53	13.40
Manufacturing (SIC 2 & 3)	1.30	3.49
Remainder Commercial/ Industrial	11.56	7.39
Military	9.30	8.42
Unaccounted	4.87	6.35
Total	39.56	39.05

VIII. EXAMPLE D — LEVEL 4 DATA

Background and Approach

STUDY AREA

The Example D forecast is performed for a portion of a major SMSA on the coastal plain of mid-Atlantic state. The study centers on a small city and surrounding residential area located approximately 30 miles from the SMSA center. The city has a population of 45,000 and significant industrial employment, including petroleum refineries and shipyards. The surrounding area includes 12 small, largely urbanized municipalities.

The study area is identical to the service area of a quasi-independent water authority, which includes the city and surrounding municipalities and townships. The utility serves more than 100,000 people, as well as comparatively large commercial and industrial sectors. The primary raw water source is a utility-owned impoundment more than 30 miles from the service area. Provisions have been made for emergency withdrawals from a major river 60 miles from the service area.

During the past decade, the city has experienced deteriorating economic conditions and declining population. The current unemployment rate is almost twice the national average. Recent trends suggest that further decline in services and commercial activity is inevitable. Housing stock within the city is old and frequently deteriorated; there has been little new development in recent years. Conversely, the outlying areas are, for the most part, affluent residential communities. Economic conditions and prospects in the suburbs are generally good.

The study area enjoys a cool temperate climate with mild to severe winters, accompanied by warm and humid summers. Annual precipitation is more than 40 inches; summer precipitation is generally less than 10 inches. Temperature changes are moderated by the proximity of a large estuary and the Atlantic Ocean.

FORECAST REQUIREMENTS

The forecast described here is carried out for the purpose of planning a multi-purpose water resource project, which would augment the present water source for the study area. The planning process will include the consideration of all feasible alternatives, including water conservation. The study area is the only part of the SMSA considered for inclusion in the project, due to the existing water transmission main connecting the utility service area to locations in the vicinity of the proposed project.

In order to provide the required information, the forecast method chosen must incorporate sectoral disaggregation as well as separate consideration of average day and maximum day water use. Since the capacities of the existing pipeline and of distribution storage will be investigated in the course of project planning, peak hour water use may be of interest as well. The level of disaggregation must be sufficient to permit complete evaluation of all feasible water conservation measures. Forecasts are required for the 1980-2030 period, at ten year intervals.

CHOICE OF FORECASTING METHOD

Both the intended application of the forecast (project planning including consideration of water conservation) and the nature of the study area (deteriorating commercial and industrial base with widely different trends in different parts of the residential sector) indicate a need for a highly disaggregate forecasting approach. Furthermore, data availability for the study area is comparatively good. The water utility has undertaken detailed analyses of available population data, and has prepared population forecasts for the study area. Also, billing records are routinely analyzed to determine water use by major sector (residential, commercial, industrial, public). Information available generally corresponds to Data Level 4, as defined in Section II.

Based on these considerations, the IWR-MAIN System was chosen for use in this study. The IWR-MAIN System, presently available through the Institute for Water Resources, U. S. Army Corps of Engineers, is the only available computer model capable of using Level 4 data to provide a fully disaggregate forecast. It is based on the earlier MAIN II System, developed by Hittman Associates, Inc., for the U. S. Department of the Interior (Hittman Associates, 1969). The IWR-MAIN System is a computerized forecasting system containing a range of forecasting models, parameter generating procedures, and data management techniques. It estimates water use at a highly disaggregate level and provides considerable flexibility in selecting forecast methods and assumptions. It requires little or no calibration, and can be used even where much of the specific data are unavailable.

The IWR-MAIN System takes into account four water use sectors: residential, commercial/institutional, industrial, and public and unaccounted for water uses. Each sector is further disaggregated for forecasting purposes into a number of water use categories, as shown on Table VIII-1. Up to 284 different commercial, institutional, residential, industrial and public water use categories can be used.

Water use is estimated by different methods in the various water use sectors. For the residential sector, domestic (indoor) water uses are computed by econometric demand models, which consider the price of water where appropriate. Sprinkling requirements are estimated separately, using demand models which include among other variables, area of irrigable land and price of water.

Table VIII-1. Internal Structure of the IWR-MAIN System

Sector	Categories

Residential	Metered and Sewered
	    Domestic Use
	    Sprinkling Use*
	Metered with Septic Tanks
	    Domestic Use
	    Sprinkling Use*
	Flat Rate and Sewered
	    Domestic Use
	    Sprinkling Use*
	Flat Rate with Septic Tanks
	    Domestic Use
	    Sprinkling Use*

Commercial/ Institutional	Subdivided by type of establishment: up to
	    50 categories available
	    28 categories provided

Industrial	Subdivided by 3-digit SIC Code: up to
	    200 categories available
	    140 categories provided

Public/Unaccounted	Subdivided by type of water use: up to 30
	    categories available
	    3 categories provided

*Separate sprinkling models provided for east and west U.S.

Commercial/institutional water use requirements are computed by the unit use coefficient method. Each commercial/institutional water use categories is measured by a different parameter, while the corresponding water use coefficients are derived from previous studies of these water use categories. The parameters for barber shops or beauty salons, for example, are number of chairs or stations. Hospitals and nursing homes are measured by number of beds, while churches, golf and swim clubs are measured by total membership. The water use coefficients are given in gpd per barber chair, gpd per beauty shop station, etc.

Industrial water use is estimated by the per-employee-use coefficient method. Employment figures for each firm, grouped by 3-digit SIC codes are used as water use parameters. The water use coefficients provided for each 3-digit SIC code give use in gpd per employee. Public and unaccounted for water uses are computed by per capita methods, using total service area population.

The various water use models depending on the categories being used, require predicted values for as many as several hundred parameters (such as number of housing units in a specific value class, number of square feet of office space, etc.). The IWR-MAIN System provides three alternate methods for providing parameter projections.

1. Projection by internal growth model (based on user-provided key projections of several parameters, including population, personal income and total employment);
2. Projection by extrapolation of local historic data for the parameter of interest; and
3. Use of projections made external to the IWR-MAIN System and provided by the user.

Irrespective of which (parameter projection) method or combination of methods is selected, a complete set of base year parameter data, together with a small amount of historic data, are required in the input stream. Then for each forecast year a considerable range of options, with varying data requirements, are available. When some of the parameters are not available, the IWR-MAIN System will complete an internally consistent set of parameter forecasts. Reports and summaries of water use are generated for each forecast year.

Compared to the original MAIN II System, IWR-MAIN is an enhanced, updated, and interactive version, currently being supported by IWR and accessible to Corps of Engineers users through the Boeing Computer System. The enhanced version omits some outdated data requirements, and accepts all price, income and value data in 1980 dollars. Among the new procedures provided are:

1. IWR-Edit. – An interactive procedure designed to prompt the user through the creation of a parameter data file. IWR-Edit can be used to:
   - i. Create a parameter data file.
   - ii. Resume creating a parameter data file which was not completed in a previous session.

iii. Add project data to an "estimate only" parameter data file, and
iv. Update an existing data file.

2. IWR-Run. – This procedure consists of three separate operations. Each operation is executed as required by the user's application and data requirements. IWR-Run provides interactive assistance to the user. The three operations are:
   i. Run the library modification program to ensure that required additions or changes are made to the library of water use coefficients.
   ii. Print the working library of water use coefficients.
   iii. Execute the IWR-MAIN model.

3. IWR-PRINT. – This procedure enables the user to print some or all IWR-MAIN system reports at a designated terminal.

Among other reasons for choosing the IWR-MAIN System for this forecast, flexibility and available on-line help make the program easy to learn, and greatly reduce the time required to use the System. The integrated procedures also reduce conceptual and operational errors common among new users of the original MAIN II System.

Data Collection

The IWR-MAIN System requires, at a minimum, data for a range of variables in the base year, as well as selected historical data. The methods used to collect these data are described here. The data values obtained are listed in the Appendix to this Section, which reproduces the computer program input as well as output reports.

BASE YEAR DATA

General Information

Table VIII-2 indicates the categories of general information which must be provided for the base year (1980). In addition, specific sectoral data are required, as described below.

Population corresponding to the smallest available areal units should be collected and aggregated to obtain the study area population. This method minimizes arbitrary allocations, improving accuracy. In this example, municipal, township and borough level data are used. When only a portion of a municipality is included, and data are not available for smaller units, an assumption of uniform population distribution is used to allocate population by area. Population data and other demographic information were obtained from the U. S. Census tape, provided by the state data center.

Table VIII-2. List of Base Year General Information, IWR-MAIN System

1. Calendar year of current parameter values provided.
2. Latitude of urban area being studied.
3. Longitude of urban area being studied.
4. Population of study area in base year.
5. Gross population density of study area in base year.
6. Fraction of the population which is in the 20 to 39 year age group in the base year.
7. Total employment within the study area in the base year.
8. Total employment within the study area in the transportation, communications, and utilities industries.
9. Per capita personal income of population residing within study area, expressed in 1960 dollars.
10. Total employment in service industries within the study area for the base year.
11. Department of Commerce National Composite Construction Cost Index for the base year.

Total employment data for areas smaller than a major political jurisdiction (such as a county) may be difficult to obtain. Employment data for specific categories can be identified from the U. S. Department of Commerce's County Business Patterns, a local industrial directory, etc. When certain information are aggregated to a higher level, a rational and consistent method should be derived to disaggregate such information. Other base year data may be available from statistical abstracts and related publications.

Residential Data

Residential housing data are divided among four major categories according to the type of water and sewer service provided:

1. Flat rate and septic tank
2. Flat rate and sewered
3. Metered and septic tank
4. Metered and sewered

The data required for each category are shown in Table VIII-3. Most of the necessary data are available at the political subdivision level from Census tapes. In the case of rental properties, some manipulation is needed to convert contract rents to equivalent home values. The following formula was used for this purpose.

$$F = \frac{(1+i)^N - 1}{i(1+i)^N} \qquad \text{(VIII-1)}$$

Where: F = conversion factor,
i = 1980 mortgage rate = 1.017% per month (12.2% per year), and
N = 360 months.

The product of the monthly rent and the conversion factor, F, is the estimated home value.

When two or more units share the same address, these units are treated as apartments and included in the commercial water use sector.

Commercial/Institutional Data

Base year values of selected parameters (which measure commercial/institutional water use) are needed for each commercial/institutional category (Table VIII-4). Also, base year employment for each category must be provided. Most of the required data can be collected by telephone survey. Information on numbers of hotels, motels, school enrollments, medical facilities and correctional institutions may be available through appropriate local agencies.

Some commercial and institutional parameters, such as total retail space or new and old office space, may be difficult to obtain. Personal knowledge

Table VIII-3. List of Base Year Residential Data, IWR-MAIN System

For each residential category:

1. Marginal price of water (where applicable).
2. Assessment factor.
3. Housing density expressed in dwelling units per residential acre.
4. Number of occupied housing units in a value range.
5. Population density expressed in persons per housing unit.
6. Marginal price of seasonal water (where applicable).
7. Low limit of a property value range.
8. Upper limit of a property value range.
9. Number of value ranges in low value group.
10. Number of value ranges in medium value group.
11. Number of value ranges in high value group.

Table VIII-4. List of Base Year Commercial and Institutional Parameter Data, IWR-MAIN System

Barber shop chairs	Motel area (sq. ft.)
Beauty salon stations	Drive-in movie car stalls
Bus depot area (sq. ft.)	New office building area (sq. ft.)
Car wash inside area (sq. ft.)	Old office building area (sq. ft.)
Church members	Jail and prison residents
Golf and swim club members	Restaurant seats
Bowling alley lanes	Drive-in restaurant stalls
College students (residential)	Night club patronage (per day)
Hospital beds	Retail space (sq. ft.)
Hotel area (sq. ft.)	School students, elementary
Laundromat area (sq. ft.)	School students, high
Laundry area (sq. ft.)	Service station inside area (sq. ft.)
Medical office area (sq. ft.)	Theatre seats

of the service area and discussion with (for example) real estate agencies can be helpful in estimating these parameters. Thompson et al. (1976) developed a subroutine for the MAIN System which estimates all commercial and institutional parameters. The subroutine is judged to be useful in the absence of local data. In this study, retail and office space were estimated by the subroutine, with some corrections to reflect known local conditions.

The model developed by Thompson et al. (1976) can also be used to estimate total employment figures for the study area. Alternatively, employment figures may be derived from County Business Patterns data which include total employment and total number of establishments by business type.

Industrial Data

The number of base year employees for selected three-digit SIC codes (between 200 and 399) are required by the IWR-MAIN System. Employment data are available from the U. S. Census of Manufacturers, State employment security office, and directly from local industries. Incomplete data may be estimated from average firm size figures calculated from County Business Patterns Data.

Public and Unaccounted Data

Losses in the distribution system and fire fighting water use are estimated by the IWR-MAIN System on a per capita basis. Airport water use, when applicable, is estimated from passenger volumes, available from airport officials. Other public water use categories may be added as needed.

HISTORIC DATA

The rates of change over at least one historic period must be provided for selected variables, as shown on Table VIII-5. These data are collected in the same manner, and from the same sources, as the base year data discussed above. Attention must be given, however, to the possibility of changes in categories and definitions of available data over time. No such problems were encountered in this study.

OTHER INFORMATION

The current water supply source is a surface reservoir about 30 miles west of the city, with a safe yield of 30 mgd. In addition there is a pipeline and installed pumping facility for 30 mgd withdrawal from a major river when needed. No water is imported into the area, but some 2.5 mgd is sold at wholesale to other utilities. There are plans to add small additional service areas along the transmission mains.

Table VIII-5. List of Historical Data, IWR-MAIN System

Population of study area.

Total number of single family residences.

Fraction of all residences in the medium value range (more than $25,000 value at 1980 prices, but less than $50,000).

Fraction of all residences in the high value range (at least $50,000 value at 1980 prices).

Median completed years of school by adult population.

Elementary school enrollment.

High school enrollment.

Total service industry employment.

Total medical/health care employment.

Manufacturing industry employment for each 2-digit SIC code.

Water demand has been rather constant during the past decade, with the average annual use rate, now about 26 mgd, growing only around 1.5 percent per year. Water rates use a decreasing block structure, although the first block of 25,000 gallons per month includes most residential use. No water conservation measures are now implemented or planned for implementation.

The water treatment plant is located near the raw water reservoir, and has complete treatment. Capacity is approximately 45 mgd; pumping capacity is 54 mgd. Treated water is pumped to two storage tanks from which it flows by gravity to the service area some 30 miles away. Transmission main capacity is 45 mgd. Finished water storage is located near the service area with total storage of 100 mgd. The distribution system consists of approximately 360 miles of pipeline varying in diameter from 4 inches to 36 inches. Since some of the distribution mains are 50 to 100 years old; an extensive program of main relining is underway.

Water Use Forecast

ASSUMPTIONS

Population Forecast

The population forecast must be prepared external to the IWR-MAIN System. Several existing forecasts were collected from state and local agencies. The state forecast is judged to be most satisfactory, but is only available through 2000. It is, therefore, extended to 2030, based on the growth pattern of the past three decades and other assumptions used by the state. The resulting growth rates are within the bounds of OBERS projections for the full SMSA. Each of the 13 municipalities and cities are forecast independently, then aggregated to the study area level. The resulting forecast is shown on Figure VIII-1.

Per Capita Personal Income

Per capita personal income forecasts are adapted from OBERS projections for the full SMSA, based on an assumption of similar social and economic conditions. In order to conform to the requirements of the current version of the IWR-MAIN System, income projections are stated in 1980 dollars (Figure VIII-2).

Other External Projections

The current version of the IWR-MAIN System does not provide completely satisfactory growth projections for an area with a very slow growth rate or which is experiencing a decline. To correct for such a problem, projections of total housing units, apartment units, and total school enrollment were

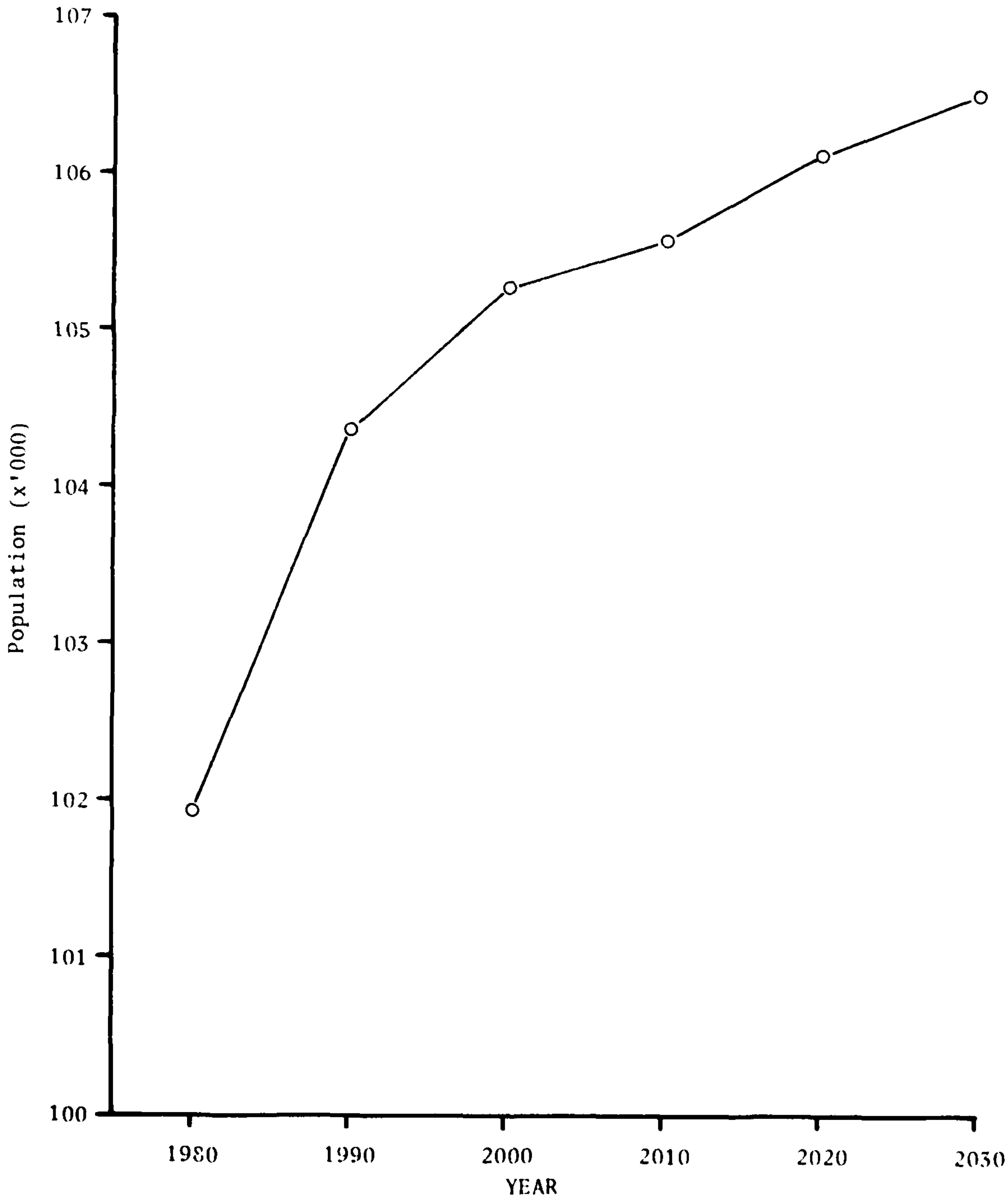

Figure VIII-1. Population Forecast, 1980-2030

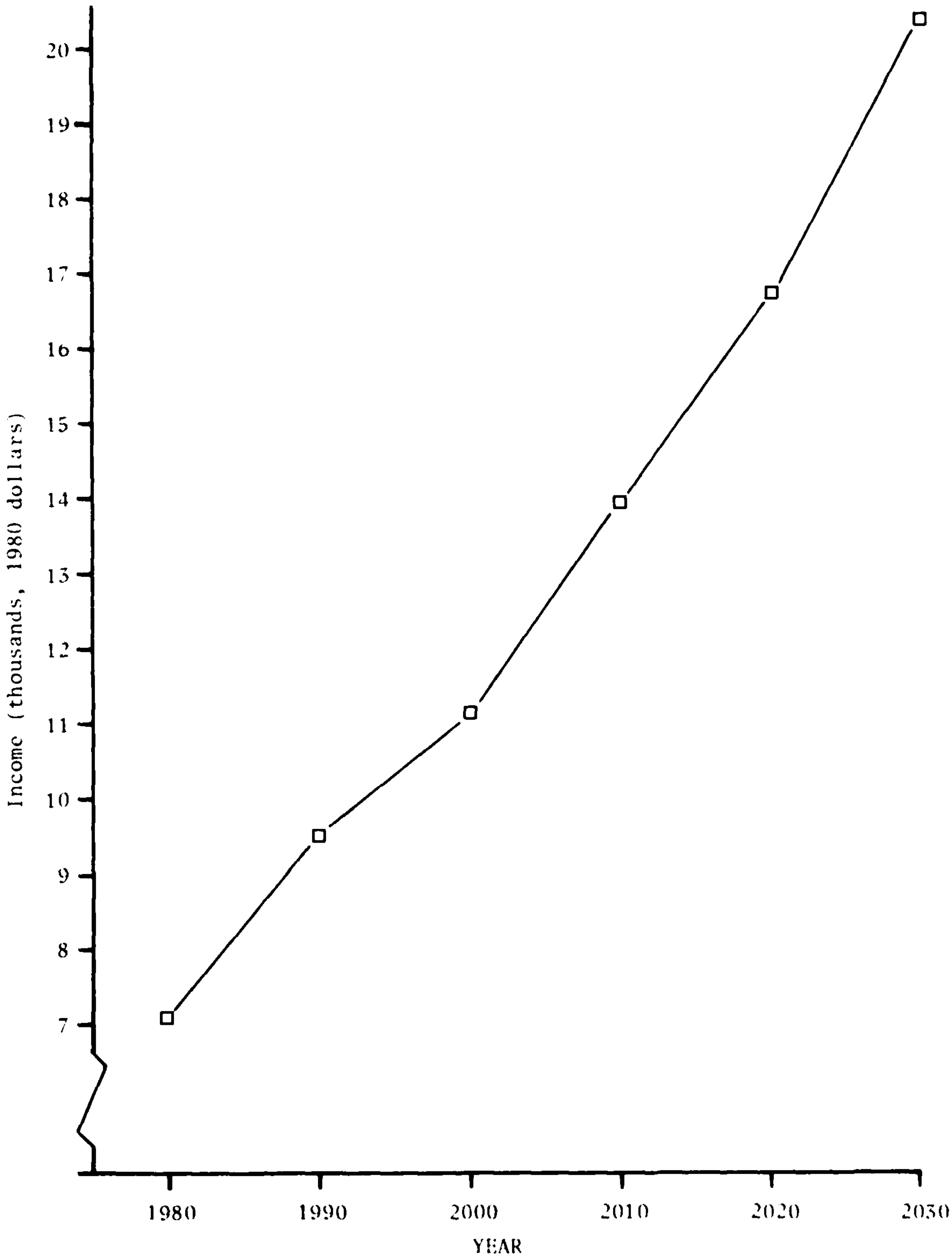

Figure VIII-2. Per Capita Personal Income Forecast
1980-2030

developed external to the IWR-MAIN system. All these projections are based on the adopted state population forecast.

Additional Water Use Categories

The original MAIN system, designed in the 1960's did not include two significant water use categories of the 1980's – apartment units and fast food restaurants. The residential water use model, in its present form, is really only suitable for single family housing units. It is able to treat apartments only as an optional commercial category. Fast food restaurants are also added to the list of commercial categories. Water use coefficients for these additional categories are then added to the library used by the IWR-MAIN system. The water use coefficient for apartments is adopted from Wolff, *et al.* [1966] while the fast food restaurant water use coefficient is derived from a sample survey of such establishments in the study area.

IWR-MAIN FORECAST

The amount of IWR-MAIN System output is determined by the data provided. All input data are printed and up to nine reports for each year developed, plus a single summary of all years. (For a complete listing, see Appendix to this Section.) The *residential* reports (an example is shown as Table VIII-6) consist of one report for each of the four categories of residential water use and a residential summary. Each report gives information on value range of housing units, number of units, domestic water use, seasonal water use, etc.

The commercial water requirement report contains both summary and detailed information on water use for all categories of commercial establishments and institutions selected by the user (Table VIII-7). Each report contains information on the type of establishment, unit of measurement, number of units, annual water use, etc.

Industrial water requirements reports contain both summary and detailed information on industrial water use, with information on industry category, number of employees, annual average water use, maximum day water use and peak hour water use (Table VIII-8).

Public and unaccounted for water use reports consist of details on water loss in the distribution system, free service water uses and any other public use categories selected (Table VIII-9).

The final report is a summary for each year analyzed. The information is broken down by water use sectors and annual average, maximum day and peak hourly use are provided (Table VIII-10).

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1980

ANALYZED BY MAIN SYSTEM

CURRENT RESIDENTIAL WATER REQUIREMENTS BY CATEGORY

METERED AND SEWERED AREAS

VALUE RANGE ($)	NO. OF UNITS	ANNUAL AVERAGE DOMESTIC	SPRINKLING	TOTAL	MAX DAY	PEAK HOUR
5000. - 9999.	2092.	349873.	51564.	401437.	505518.	1718358.
10000. - 14999.	2397.	415816.	109355.	525171.	708147.	2228931.
15000. - 19999.	3778.	678919.	243349.	922268.	1322732.	3929803.
20000. - 24999.	3736.	694647.	293183.	987835.	1519369.	4312391.
25000. - 29999.	3655.	702357.	279131.	981488.	1722097.	4694239.
30000. - 34999.	2714.	538440.	231093.	769533.	1440800.	3812559.
35000. - 39999.	1820.	372415.	136256.	508671.	1099237.	2825041.
40000. - 49999.	2852.	610238.	166948.	777186.	2066399.	5120495.
50000. - 79999.	5031.	1213792.	253610.	1467402.	5263737.	12314012.
80000. - 99999.	337.	91003.	21575.	112578.	466941.	1054379.
100000. - 149999.	115.	36070.	9880.	45950.	215040.	472146.
150000. - 199999.	23.	8547.	2575.	11222.	59260.	127210.
200000. - 300000.	8.	3755.	564.	4319.	32146.	67510.
TOTAL	23608.	5715971.	1799089.	7515060.	16421424.	42677034.

Table VIII-6. Example of Residential Water Requirements Report, 1980

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1980

ANALYZED BY MAIN SYSTEM

TOTAL COMMERCIAL REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
3196481.	5299975.	12968400.

WATER REQUIREMENTS BY TYPE OF COMMERCIAL ESTABLISHMENT

TYPE	UNITS	NUMBER OF UNITS	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
			(GALLONS	PER	DAY)
HOTELS	SQ. FT.	159078.	40724.	46769.	68381.
MOTELS	SQ. FT.	154713.	34656.	71323.	239805.
BARBER SHOPS	BARBER CHAIR	65.	3549.	5220.	25285.
BEAUTY SHOPS	STATION	285.	76665.	93480.	304950.
RESTAURANTS	SEAT	4396.	106383.	366626.	734132.
NIGHT CLUBS	PERSON SERVED	4720.	6278.	6278.	6278.
HOSPITALS	BED	623.	217288.	346028.	572736.
NURSING HOMES .	BED	401.	53333.	58546.	170024.
MEDICAL OFFICES	SQ. FT.	218195.	134845.	362204.	1084429.
LAUNDRY	SQ. FT.	37962.	9604.	12376.	59600.
LAUNDROMATS	SQ. FT.	35752.	78016.	173412.	234048.
RETAIL SPACE	SALES SQ. FT.	1549125.	164207.	238565.	419313.
SCHOOL,ELEM.	STUDENT	10733.	57770.	103944.	527236.
SCHOOL, HIGH	STUDENT	15231.	100982.	298528.	1842951.
BUS-RAIL DEPOTS	SQ. FT.	1500.	4995.	9750.	37500.
CAR WASHES	INSIDE SQ. FT.	13264.	63402.	136619.	417816.
CHURCHES	MEMBER	43834.	6049.	37785.	206020.
GOLF-SWIM CLUBS	MEMBER	850.	26350.	18870.	18870.
BOWLING ALLEYS	ALLEY	24.	3192.	3192.	3192.
COLLEGES RESID.	STUDENT	1279.	135574.	145806.	319750.
NEW OFFICE BLDG.	SQ. FT.	453090.	42137.	78335.	236060.
OLD OFFICE BLDG.	SQ. FT.	655200.	93638.	53071.	231941.
THEATERS	SEAT	600.	1998.	1998.	1998.
SERVICE STATIONS	INSIDE SQ. FT.	54444.	13665.	32122.	1714986.
APARTMENTS	OCCUPIED UNITS	7720.	1675240.	2509000.	3350480.
FAST FOOD REST.	ESTABLISHMENT	26.	48540.	93080.	139620.

Table VIII-7. Example of Commercial Requirements Report, 1980

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1980

ANALYZED BY MAIN SYSTEM

TOTAL INDUSTRIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
11131335.	11131335.	11131335.

REQUIREMENTS BY TYPE OF INDUSTRY

CODE	INDUSTRY CATEGORY	NUMBER OF EMPLOYEES	GALLONS/DAY ANNUAL AVERAGE	MAXIMUM DAY	PEAK HOUR
201	MEAT PRODUCTS	204.	184394.	184394.	184394.
230	WHL.APPAREL IND.	68.	1360.	1360.	1360.
249	MISCELL. WOOD	35.	5066.	5066.	5066.
264	PAPER PRODUCTS	307.	133788.	133788.	133788.
270	WHOL.PRINT IND.	136.	2040.	2040.	2040.
281	BASIC CHEMICALS	390.	1070316.	1070316.	1070316.
282	FIBERS. PLASTICS	60.	51894.	51894.	51894.
284	SOAP-TOILET GOOD	86.	57796.	57796.	57796.
291	PETROLEUM REFIN.	2372.	7450689.	7450689.	7450689.
295	PAVING-ROOFING	7.	5807.	5807.	5807.
327	CEMENT-PLASTER	90.	31841.	31841.	31841.
329	NONMETALLIC MNRL	60.	26374.	26374.	26374.
336	NONFERROUS FOUND	42.	40723.	40723.	40723.
339	PRIME METAL IND.	300.	149499.	149499.	149499.
343	PLUMBING,HEATING	20.	8232.	8232.	8232.
344	STRUCTURE METAL	285.	91164.	91164.	91164.
346	METAL STAMPINGS	22.	10191.	10191.	10191.
347	METAL SERVICES	5.	9033.	9033.	9033.
349	FABRICATED METAL	370.	100339.	100339.	100339.
354	METALWORK.MACHRY	70.	13738.	13738.	13738.
355	SPECL INDUS.MACH	81.	23530.	23530.	23530.
356	GENRL IND. MACH.	22.	5427.	5427.	5427.
358	SERV. IND. MACH.	65.	15039.	15039.	15039.
359	MISCELL. MACHINE	105.	25078.	25078.	25078.
362	ELECT.IND.APPART	25.	8400.	8400.	8400.
366	COMMUNICATION EQ	28.	2416.	2416.	2416.
371	MOTOR VEHICLES	52.	16548.	16548.	16548.
373	SHIP & BOAT BLDG	2090.	347095.	347095.	347095.
391	JEWELRY, SILVER	3400.	1042069.	1042069.	1042069.
399	MISCEL. MANUFACT	780.	201451.	201451.	201451.

Table VIII-8. Example of Industrial Water Requirements Report, 1980

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1980

ANALYZED BY MAIN SYSTEM

TOTAL PUBLIC-UNACCOUNTED REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
2049014.	2049014.	2049014.

REQUIREMENTS BY TYPE OF PUBLIC-UNACCOUNTED USAGE IN GALLONS PER DAY

TYPE	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
DISTRIB. LOSSES	1518921.	1518921.	1518921.
FREE SERVICES	530093.	530093.	530093.

Table VIII-9. Example of Public and Unaccounted Water Use Report, 1980

SUMMARY OF MUNICIPAL WATER REQUIREMENTS FOR CITY OF LEVEL 4 DATA STUDY

ESTIMATED WATER REQUIREMENTS FOR YEAR 1980.
(ALL VALUES IN GALLONS PER DAY)

	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
MUNICIPAL	23891889.	32798254.	59053914.
RESIDENTIAL	7515060.	16421424.	42677084.
COMMERCIAL	3196481.	5299975.	12968400.
INDUSTRIAL	11131335.	11131335.	11131335.
PUBLIC AND UNACC.	2049014.	2049014.	2049014.

Table VIII-10. Example of Annual Summary Report, 1980

The total water use estimate for the current year is very close to the records of the local water utility, but there are differences in the distribution of water use among user sectors. Table VIII-11 summarizes comparison of base year results.

The noticeable differences are high IWR-MAIN System estimates for residential and commercial/institutional water use, and a low estimate for public and unaccounted water use. The overestimation of residential water use could affect domestic or seasonal water use, or both, as no actual seasonal data are available for comparison. Overestimation in the commercial/institutional sector may be due to errors in parameter estimates from secondary data sources, or to outdated library values for water use coefficients which may not accurately reflect the current local, social and economic conditions.

On the other hand, public and unaccounted water use is underestimated by more than 3 mgd. The record provided by the local utility for public and unaccounted water use amounts to 22 percent of the total water use. By comparison to other utilities, this figure is very high. There are reasons to suspect that part of the recorded public and unaccounted water use is the result of meter misregistration (the recorded per capita residential water use rate, for example, is low by comparison to nearby utilities). The distribution system in the central city is 50 to 100 years old and many residential and commercial meters have been in service many decades. Smaller residential and commercial meters are less likely to be tested and/or replaced than are larger industrial meters. It is likely that a substantial portion of the reported public and unaccounted-for water use is due to meter misregistration, and should appear as higher reported water use for residential and commercial/institutional sectors. If true, this would greatly improve agreement with the IWR-MAIN system results for the base year.

Municipal water use forecasts from 1980 to 2030, in ten-year intervals, are obtained from the IWR-MAIN system results and shown as Table VIII-12. Average day water use is also plotted as Figure VIII-3. Forecast municipal water use increases at an average rate of about 0.4 percent per year for 50 years. The relative water use among sectors remains similar over time, except for a slight, relative decline in commercial/institutional water use, and a gradual relative increase in the industrial sector.

Analysis of Results

DATA AND MODEL LIMITATIONS

The IWR-MAIN system is capable of preparing highly disaggregate forecasts of future water use, based on a moderate quantity of data. The data, however, must be of relatively good quality and may be judged difficult to collect, when compared to data required by other forecast methods. In the case of this example forecast, approximately 30 to 40 man-days were needed

Table VIII-11. Summary of Recorded and Estimated 1980 Water Use

	Utility Records		IWR-MAIN System	
	mgd	% of Total	mgd	% of Total
Municipal*	23.71	100.00	23.89	100.00
Residential	5.00	21.09	7.52	31.03
Commercial/ Institutional	1.45	6.12	3.20	13.47
Industry	12.02	50.70	11.13	46.87
Public/ Unaccounted	5.24	22.10	2.05	8.63

* Excludes wholesale transfers to other utilities.

Table VIII-12. Summary of Forecast Water Use, 1980-2030 (mgd)

	1980	1990	2000	2010	2020	2030
Municipal* (average day)	23.89	24.66	25.67	26.98	28.24	29.51
Residential	7.52	7.93	8.23	8.70	9.01	9.34
Commercial/Institutional	3.20	2.86	2.91	2.98	3.06	3.13
Industrial	11.13	11.77	12.41	13.18	14.04	14.90
Public/Unaccounted	2.05	2.10	2.12	2.12	2.13	2.14
Municipal* (maximum day)	32.80	33.90	35.07	36.74	38.19	39.69
Municipal* (peak hour)	59.05	61.38	63.30	66.34	68.57	70.97

* Excludes wholesale transfers to other utilities.

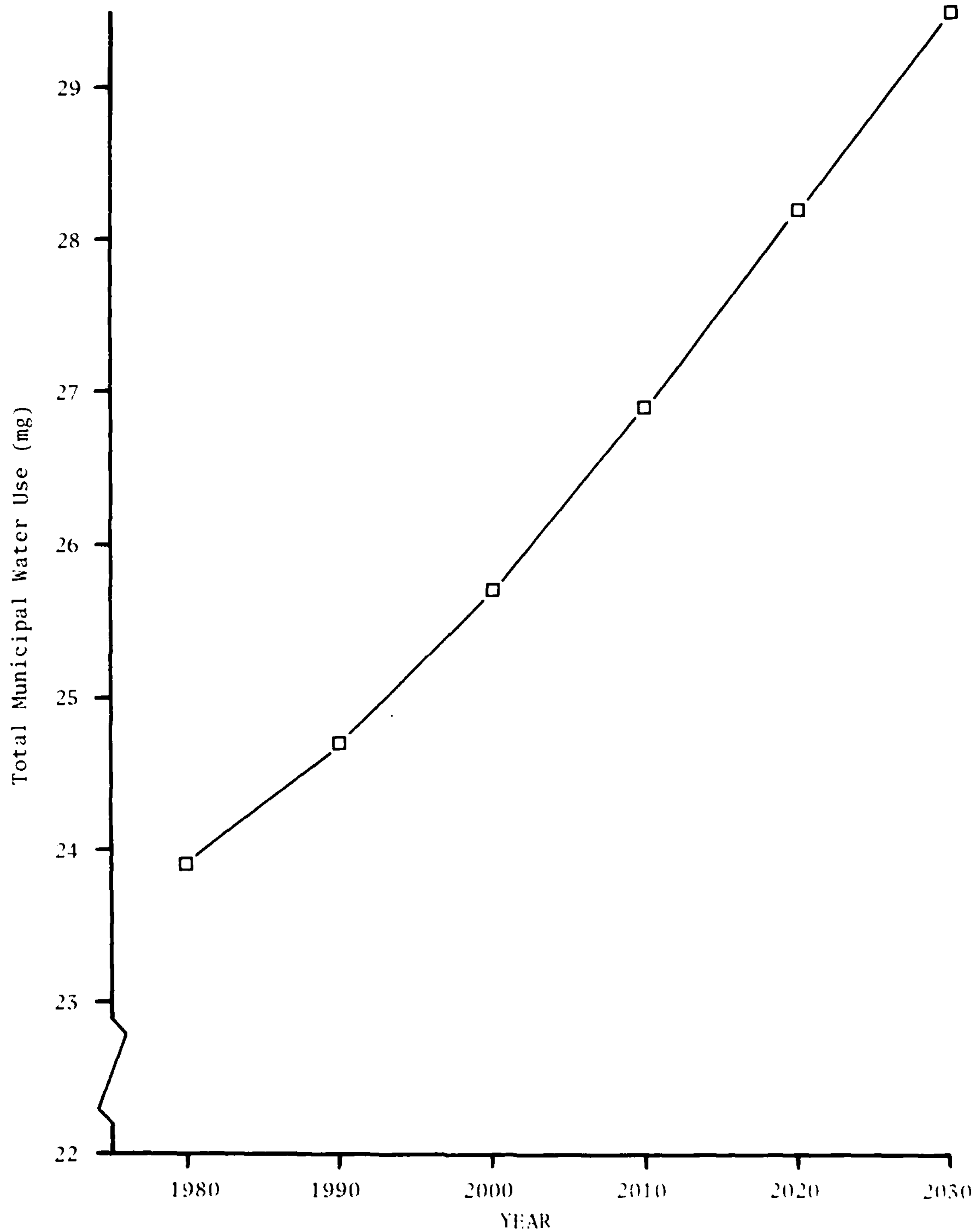

Figure VIII-3. Municipal Water Use Forecast, 1980-2030 to collect and prepare the data used. The data collection effort may be reduced with experience, but can still be excessive in certain applications.

In order that the high level of disaggregation and detail provided by the IWR-MAIN system result in improved forecast accuracy, the quality of the data used must be relatively high, especially those data describing base year conditions. Since primary data collection (surveys, actual counts, etc.) is feasible for only a few of the commercial/institutional parameters, almost all data must be obtained from secondary sources (government statistics, local agencies, etc.). Every effort should be made to locate the most reliable source for each type of data needed. In some cases, no source will be found; those data must be replaced by subjective estimates. In every case, estimates should be performed by the individual having the most complete knowledge of the process to which the estimate applies. For example, grade school enrollment may be estimated by a school administrator, total office space by a chamber of commerce official or a commercial realtor, etc.

Poor quality forecast year data is less important to the ultimate water use forecast than similar problems with base year data. Inaccuracies in base year data alter resulting forecasts in complex and subtle ways, not readily discernible to the analyst. Errors in data provided for a given forecast year, on the other hand, affect water use estimates for that year only, and in a way which is readily seen by examination of the projected parameters used to calculate water use. Where these parameters seem inconsistent, alternate forecasts can be prepared with different data values, thus revealing the sensitivity of future water use to changes in the forecast year data.

The internal growth models presently contained within the IWR-MAIN system have certain deficiencies which became evident in the preparation of this example. The system assumes a large city or SMSA which has experienced, and expects to continue positive growth. Also, the internal growth models, designed primarily for certain of the built-in water use categories, do not always function well for user-added categories. Certain aspects of water use patterns, such as those resulting from conservation practices, might have changed significantly from the 1960's.

In spite of these shortcomings the IWR-MAIN system remains a powerful accounting tool for estimating and forecasting water uses. When base year data are available, the model allows planners to investigate alternative scenarios in socioeconomic conditions and growth assumptions, and observe the consequences for patterns and levels of water use.

PROBLEMS ENCOUNTERED

The IWR-MAIN system is quite complex. The interactions among parameters and their effects on water use are not easy to understand without considerable study of the forecast models and assumptions. The limitations of the growth models, noted above, led to erroneous initial forecasts of certain parameters; for example, number of apartment units. The growth models built into the IWR-MAIN system do not produce the desired growth trends for these added user categories. To circumvent the problem, external forecasts consistent with population forecasts were provided to the IWR-MAIN system. The external forecasts were proportionally adjusted to obtain the desired outcome without modifying the model. Similar problems were encountered with school enrollments and total number of housing units. In both cases, external forecasts, consistent with the population projections, were provided to override the internal growth models.

WITH- VS. WITHOUT-PROJECT CONDITIONS

The forecast summarized on Table VIII-12, and detailed in the Appendix to this Section, represents without-project conditions in the study area. Should the proposed project be constructed, water use would be affected in two ways:

1. The future price of water, presently assumed to remain constant in real terms, would be reduced by 5 percent after 1990; and
2. The future per capita income in the service area will exceed without-project projections by a constant 2 percent after 1990 as a consequence of project-induced economic activity.

Due to the comparatively remote location of the project, no land use-related or other effects are expected.

The IWR-MAIN System was used to obtain another set of forecasts incorporating the with-project levels of water price and per capita income, with all other assumptions and data unchanged. These forecasts are summarized on Table VIII-13. Average day water use is seen to increase slightly (about 0.25 mgd) over the affected period (2000-2030) (see Table VIII-12). Maximum day water use increases relatively more, as much as 0.93 mgd in 2030.

APPLICATION OF RESULTS

The forecast produced by the IWR-MAIN system can be used for facility planning at all levels of water supply, transmission, treatment, and distribution. In addition to average day water use forecasts, estimates of maximum day and peak hour water use are prepared, providing useful design factors. Perhaps more importantly, the model reveals possible differential growth trends among sectors which may become critical to future facility requirements. The ease with which assumptions can be changed to provide alternative scenarios or conditional forecasts is perhaps the strongest point in favor of the IWR-MAIN system. Where sufficient effort can be devoted to

Table VIII-13. With-Project Water Use Forecast
2000 - 2030 (mgd)

Year	Mean Annual	Max Day	Peak Hour
2000	25.91	35.89	64.96
2010	27.24	37.61	68.08
2020	28.51	39.08	70.36
2030	29.79	40.62	72.83

data collection, the IWR-MAIN system provides a detailed and credible forecast, which yields information of considerable use to the planning process.

COMPARISON WITH OTHER FORECASTS

The only other known forecast for the planning area was prepared almost simultaneously with the example forecast by the local water utility. The forecasts are compared in Table VIII-14. The IWR-MAIN system produced lower 7.5 percent lower for 1990 and 11.7 percent lower for 2000. These differences result in part from differences in the population projections used. The local utility relied on locally prepared projections, which were more optimistic about future growth than was the state projection used in the IWR-MAIN system forecast. Had the local forecast been based on the same population forecast used here, however, the IWR-MAIN forecast would have again been lower, by 2.9 percent in 1990 and by 0.5 percent in 2000.

Table VIII-14. Comparison With Other Forecast (mgd)

Year	MAIN Forecast	Utility Forecast*
1980	23.9	23.7
1990	24.7	26.7
2000	25.7	29.1
2010	27.0	--
2020	28.2	--
2030	29.5	--

* 2.5 wholesale water use excluded.

APPENDIX

LISTING OF MAIN II SYSTEM INPUT DATA AND OUTPUT REPORTS

```
REDINP  OPTIONS


     DISPLAY OPTIONS

MACH          175.000
PROJ            2.000
LBIN            1.000
ENDD            0.000
REDINP  CITYDATA


     CITY  DATA

LEVEL 4 DATA STUDY
CDAT         1930.000
LATD           39.865
LONG           75.363
POPU       101941.000
PDEN         3842.340
POPP             .280
EMPL        43295.000
EMTC         1170.000
ICOM         7123.270
TSER        12651.000
CCBN          103.000
ENDD            0.000
REDINP  METRSEWR


VALN         5000.000
VALX         9999.000
ANPR          103.000
DENS           17.000
NUMB         2092.000
SMPR          103.000
VALN        10000.000
VALX        14999.000
ANPR          103.000
DENS           15.000
NUMB         2397.000
SMPR          103.000
VALN        15000.000
VALX        19999.000
ANPR          103.000
DENS           13.000
NUMB         3778.000
SMPR          103.000
VALN        20000.000
VALX        24999.000
ANPR          103.000
DENS           11.000
```

```
NUMB         3736.000
SMPR          103.000
VALN        25000.000
VALX        29999.000
ANPR          103.000
DENS            8.000
NUMB         3655.000
SMPR          103.000
VALN        30000.000
VALX        34999.000
ANPR          103.000
DENS            7.000
NUMB         2714.000
SMPR          103.000
VALN        35000.000
VALX        39999.000
ANPR          103.000
DENS            5.000
NUMB         1820.000
SMPR          103.000
VALN        40000.000
VALX        49999.000
ANPR          103.000
DENS            3.000
NUMB         2852.000
SMPR          103.000
VALN        50000.000
VALX        79999.000
ANPR          103.000
DENS            1.500
NUMB         5081.000
SMPR          103.000
VALN        80000.000
VALX        99999.000
ANPR          103.000
DENS            1.200
NUMB          337.000
SMPR          103.000
VALN       100000.000
VALX       149999.000
ANPR          103.000
DENS            1.000
NUMB          115.000
SMPR          103.000
VALN       150000.000
VALX       199999.000
ANPR          103.000
DENS             .800
NUMB           23.000
SMPR          103.000
VALN       200000.000
VALX       300000.000
ANPR          103.000
DENS             .300
NUMB            8.000
SMPR          103.000
LOWV            4.000
MEDN            4.000
HIGH            5.000
ENDD            0.000
```

```
REDINP  COMMPARM


HOTL       159078.000
MOTL       154713.000
BARB           65.000
BEUT          285.000
EATN         4396.000
NITE         4720.000
HOSP          628.000
NURS          401.000
MEDL       218195.000
LNDY        37962.000
LNDM        35952.000
SALE      1549125.000
SKLL        10738.000
SKLH        15231.000
DPOT         1500.000
CARW        13264.000
CHUR        43834.000
CLUB          850.000
BOWL           24.000
COLG         1279.000
OFFN       453090.000
OFFO       655200.000
THTR          600.000
GASS        54444.000
C001         7720.000
C002           26.000
ENDD            0.000
REDINP  COMMEMPL


HOTL          120.000
MOTL           60.000
BARB           63.000
BEUT          286.000
EATN          800.000
NITE          282.000
HOSP         1904.000
NURS          321.000
MEDL          480.000
LNDY          144.000
LNDM            5.000
SALE         6676.000
DPOT           10.000
CARW           79.000
CHUR          651.000
CLUB           32.000
BOWL           20.000
COLG           42.000
OFFN         3081.000
OFFO         2347.000
THTR           15.000
GASS          221.000
C001            1.000
C002          529.000
ENDD            0.000
```

```
REDINP  INDPARAM

I201        204.000
I230         68.000
I249         35.000
I264        307.000
I270        136.000
I281        390.000
I232         60.000
I284         86.000
I291       2372.000
I295          7.000
I327         90.000
I329         60.000
I336         42.000
I339        300.000
I343         20.000
I344        285.000
I346         22.000
I347          5.000
I349        370.000
I354         70.000
I355         81.000
I356         22.000
I358         45.000
I359        105.000
I362         25.000
I366         28.000
I371         52.000
I373       2090.000
I391       3400.000
I399        780.000
ENDD          0.000
REDINP  POPULATN

YEAR       1970.000
DATA     109931.000
YEAR       1980.000
DATA     101941.000
ENDD          0.000
REDINP  NONWHITE

YEAR       1970.000
DATA           .100
YEAR       1980.000
DATA           .100
ENDD          0.000
REDINP  ALLHOMES

YEAR       1970.000
DATA      33757.000
YEAR       1980.000
DATA      28608.000
ENDD          0.000
REDINP  MEDHOMES

YEAR       1970.000
DATA           .459
YEAR       1980.000
DATA           .386
ENDD          0.000
REDINP  HIGHOMES

YEAR       1970.000
DATA           .189
YEAR       1980.000
DATA           .194
ENDD          0.000
REDINP  SKOLYEAR

YEAR       1970.000
DATA         11.200
YEAR       1980.000
DATA         11.100
ENDD          0.000
REDINP  ELEMSKOL

YEAR       1970.000
DATA      14919.000
YEAR       1980.000
DATA      10738.000
ENDD          0.000
REDINP  HIGHSKOL

YEAR       1970.000
DATA      17164.000
YEAR       1980.000
DATA      15231.000
ENDD          0.000
REDINP  TSERVICE

YEAR       1970.000
DATA      10619.000
YEAR       1980.000
DATA      12651.000
ENDD          0.000
REDINP  MEDICALS

YEAR       1970.000
DATA       2035.000
YEAR       1980.000
DATA       2384.000
ENDD          0.000
REDINP  INDHISTY

YEAR       1970.000
POPU     109931.000
ICOM       3252.000
EMPL      44325.000
I200        137.000
I210          0.000
I220          0.000
I230         75.000
I240         44.000
I250         55.000
I260        350.000
I270        150.000
I300          0.000
I330        650.000
I340       1084.000
I370       2700.000
I400       1270.000
YEAR       1980.000
POPU     101941.000
ICOM       4037.700
EMPL      43295.000
I200        204.000
I210          0.000
I220          0.000
I230         68.000
I240         35.000
I250          0.000
I260        307.000
I270        136.000
I300          0.000
I330        342.000
I340        702.000
I370       2142.000
I400       1170.000
ENDD          0.000
REDINP  NEWYEAR

YEAR       1990.000
POPU     104389.000
ICOM       9462.000
ENDD          0.000
NUMHOMES
MWTL      29977.000
ENDD          0.000
COMFPARM
SKLL      11545.000
SKLH      14469.000
C001      11919.000
ENDD          0.000
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COMFEMPL
C001            1.000
ENDD            0.000
ENDYEAR
REDINP   NEWYEAR


YEAR         2000.000
POPU       105292.000
ICOM        11537.000
ENDD            0.000
NUMHOMES
MWTL        30864.000
ENDD            0.000
COMFPARM
SKLL        11201.000
SKLH        13383.000
C001        12568.000
ENDD            0.000
COMFEMPL
C001            1.000
ENDD            0.000
ENDYEAR
REDINP   NEWYEAR


YEAR         2010.000
POPU       105663.000
ICOM        13870.000
ENDD            0.000
NUMHOMES
MWTL        32399.000
ENDD            0.000
COMFPARM
SKLL        11130.000
SKLH        13335.000
C001        13143.000
ENDD            0.000
COMFEMPL
C001            1.000
ENDD            0.000
ENDYEAR
REDINP   NEWYEAR


YEAR         2020.000
POPU       106150.000
ICOM        16672.000
ENDD            0.000
NUMHOMES
MWTL        33266.000
ENDD            0.000
COMFPARM
SKLL        10957.000
SKLH        12933.000
C001        13729.000
ENDD            0.000
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COMFEMPL
C001            1.000
ENDD            0.000
ENDYEAR
REDINP   NEWYEAR


YEAR         2030.000
POPU       106545.000
ICOM        20040.000
ENDD            0.000
NUMHOMES
MWTL        34210.000
ENDD            0.000
COMFPARM
SKLL        10998.000
SKLH        12804.000
C001        14185.000
ENDD            0.000
COMFEMPL
C001            1.000
ENDD            0.000
ENDYEAR
REDINP   ENDI
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MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1980

ANALYZED BY MAIN SYSTEM

CURRENT RESIDENTIAL WATER REQUIREMENTS BY CATEGORY

METERED AND SEWERED AREAS

VALUE RANGE ($)	NO. OF UNITS	ANNUAL AVERAGE DOMESTIC	ANNUAL AVERAGE SPRINKLING	ANNUAL AVERAGE TOTAL	MAX DAY	PEAK HOUR
5000. - 9999.	2092.	349873.	51564.	401437.	505518.	1718358.
10000. - 14999.	2397.	415816.	109355.	525171.	708147.	2228931.
15000. - 19999.	3778.	678917.	243349.	922266.	1322732.	3929803.
20000. - 24999.	3736.	694647.	293188.	987835.	1519369.	4312391.
25000. - 29999.	3655.	702357.	279131.	981488.	1722097.	4694239.
30000. - 34999.	2714.	538440.	231093.	769533.	1440809.	3812559.
35000. - 39999.	1820.	372415.	136256.	508671.	1099237.	2825041.
40000. - 49999.	2852.	610238.	166948.	777186.	2566399.	5120495.
50000. - 79999.	5031.	1213792.	253610.	1467402.	5263737.	12314012.
80000. - 99999.	337.	91003.	21575.	112578.	466941.	1054379.
100000. - 149999.	115.	36070.	9880.	45950.	215040.	472146.
150000. - 199999.	23.	8647.	2575.	11222.	59260.	127210.
200000. - 300000.	8.	3755.	564.	4319.	32146.	67510.
TOTAL	28608.	5715971.	1799089.	7515060.	16421424.	42677054.

CURRENT RESIDENTIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
7515060.	16421424.	42677084.

REQUIREMENTS BY TYPE - ANNUAL AVERAGE

TYPE	NO. OF UNITS	GALLONS PER DAY DOMESTIC	SPRINKLING	TOTAL
METERED AND SEWERED AREAS	28608.	5715971.	1799089.	7515060.
TOTAL	28608.	5715971.	1799089.	7515060.

SUMMER EVAPOTRANSPIRATION (INCHES) = 16.25

SUMMER PRECIPITATION (INCHES) = 7.75

MAX. DAY EVAPOTRANSPIRATION (INCHES) = .29

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1980

ANALYZED BY MAIN SYSTEM

TOTAL COMMERCIAL REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
3196481.	5299975.	12958400.

WATER REQUIREMENTS BY TYPE OF COMMERCIAL ESTABLISHMENT

TYPE	UNITS	NUMBER OF UNITS	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
			(GALLONS	PER DAY	)
HOTELS	SQ. FT.	159078.	40724.	46769.	68381.
MOTELS	SQ. FT.	154713.	34656.	71323.	239835.
BARBER SHOPS	BARBER CHAIR	65.	3549.	5220.	25285.
BEAUTY SHOPS	STATION	285.	76665.	93480.	304950.
RESTAURANTS	SEAT	4396.	106333.	366626.	734132.
NIGHT CLUBS	PERSON SERVED	4720.	6278.	6278.	6278.
HOSPITALS	BED	623.	217288.	346028.	572736.
NURSING HOMES	BED	401.	53333.	58546.	170024.
MEDICAL OFFICES	SQ. FT.	218195.	139845.	362204.	1084429.
LAUNDRY	SQ. FT.	37962.	9604.	12376.	59600.
LAUNDROMATS	SQ. FT.	35952.	78016.	173412.	234048.
RETAIL SPACE	SALES SQ. FT.	1549125.	164207.	238565.	419813.
SCHOOL, ELEM.	STUDENT	10733.	57770.	103944.	527236.
SCHOOL, HIGH	STUDENT	15231.	100932.	298528.	1842951.
BUS-RAIL DEPOTS	SQ. FT.	1500.	4995.	9750.	37500.
CAR WASHES	INSIDE SQ. FT.	13264.	63402.	136519.	417816.
CHURCHES	MEMBER	43834.	6049.	37785.	206020.
GOLF-SWIM CLUBS	MEMBER	850.	26350.	12070.	18970.
BOWLING ALLEYS	ALLEY	24.	3192.	3192.	3192.
COLLEGES RESID.	STUDENT	1279.	135574.	145806.	319750.
NEW OFFICE BLDG.	SQ. FT.	453390.	42137.	78385.	236060.
OLD OFFICE BLDG.	SQ. FT.	655200.	93038.	53071.	231941.
THEATERS	SEAT	600.	1998.	1998.	1998.
SERVICE STATIONS	INSIDE SQ. FT.	54444.	13665.	32122.	1719986.
APARTMENTS	OCCUPIED UNITS	7720.	1675240.	2509000.	3350480.
FAST FOOD REST.	ESTABLISHMENT	26.	46540.	93080.	139620.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1980

ANALYZED BY MAIN SYSTEM

TOTAL INDUSTRIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
11131335.	11131335.	11131335.

REQUIREMENTS BY TYPE OF INDUSTRY

CODE	INDUSTRY CATEGORY	NUMBER OF EMPLOYEES	GALLONS/DAY ANNUAL AVERAGE	MAXIMUM DAY	PEAK HOUR
201	MEAT PRODUCTS	204.	184394.	184394.	184394.
230	WHL.APPAREL IND.	68.	1360.	1360.	1360.
249	MISCELL. WOOD	35.	5066.	5066.	5066.
264	PAPER PRODUCTS	307.	133788.	133788.	133788.
270	WHOL.PRINT IND.	136.	2040.	2040.	2040.
281	BASIC CHEMICALS	390.	1070316.	1070316.	1070316.
282	FIBERS, PLASTICS	60.	51894.	51894.	51894.
284	SOAP-TOILET GOOD	86.	57796.	57796.	57796.
291	PETROLEUM REFIN.	2372.	7450689.	7450689.	7450689.
295	PAVING-ROOFING	7.	5807.	5807.	5807.
327	CEMENT-PLASTER	90.	31841.	31841.	31841.
329	NONMETALLIC MNRL	60.	26374.	26374.	26374.
336	NONFERROUS FOUND	42.	40723.	40723.	40723.
339	PRIME METAL IND.	300.	149499.	149499.	149499.
343	PLUMBING,HEATING	20.	8232.	8232.	8232.
344	STRUCTURE METAL	285.	91164.	91164.	91164.
346	METAL STAMPINGS	22.	10191.	10191.	10191.
347	METAL SERVICES	5.	9033.	9033.	9033.
349	FABRICATED METAL	370.	100339.	100339.	100339.
354	METALWORK.MACHRY	70.	13738.	13738.	13738.
355	SPECL INDUS.MACH	81.	23530.	23530.	23530.
356	GENRL IND. MACH.	22.	5427.	5427.	5427.
358	SERV. IND. MACH.	45.	15039.	15039.	15039.
359	MISCELL. MACHINE	105.	25078.	25078.	25078.
362	ELECT.IND.APPART	25.	8400.	8400.	8400.
366	COMMUNICATION EQ	28.	2416.	2416.	2416.
371	MOTOR VEHICLES	52.	16548.	16548.	16548.
373	SHIP & BOAT BLDG	2090.	347095.	347095.	347095.
391	JEWELRY, SILVER	3400.	1042069.	1042069.	1042069.
399	MISCEL. MANUFACT	780.	201451.	201451.	201451.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1980

ANALYZED BY MAIN SYSTEM

TOTAL PUBLIC-UNACCOUNTED REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
2049014.	2049014.	2049014.

REQUIREMENTS BY TYPE OF PUBLIC-UNACCOUNTED USAGE IN GALLONS PER DAY

TYPE	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
DISTRIB. LOSSES	1518921.	1518921.	1518921.
FREE SERVICES	530093.	530093.	530093.

SUMMARY OF MUNICIPAL WATER REQUIREMENTS FOR CITY OF LEVEL 4 DATA STUDY

ESTIMATED WATER REQUIREMENTS FOR YEAR 1980.
(ALL VALUES IN GALLONS PER DAY)

	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
MUNICIPAL	23891889.	32798254.	59053914.
RESIDENTIAL	7515060.	16421424.	42677084.
COMMERCIAL	3196481.	5299975.	12968400.
INDUSTRIAL	11131335.	11131335.	11131335.
PUBLIC AND UNACC.	2049014.	2049014.	2049014.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1990

ANALYZED BY MAIN SYSTEM

PREDICTED RESIDENTIAL WATER REQUIREMENTS BY CATEGORY

METERED AND SEWERED AREAS

VALUE RANGE ($)	NO. OF UNITS	DOMESTIC	SPRINKLING	TOTAL	MAX DAY	PEAK HOUR
		ANNUAL AVERAGE				
5000. - 9999.	1831.	306256.	45136.	351392.	442498.	1504139.
10000. - 14999.	2098.	363978.	95722.	459701.	619866.	1951062.
15000. - 19999.	3307.	594282.	213012.	807294.	1157834.	3439894.
20000. - 24999.	3270.	608049.	256638.	864687.	1329957.	3774787.
25000. - 29999.	4854.	932707.	370677.	1303384.	2286838.	6233795.
30000. - 34999.	3604.	715030.	306884.	1021914.	1913334.	5052956.
35000. - 39999.	2417.	494554.	180943.	675498.	1459750.	3751561.
40000. - 49999.	3787.	810376.	221701.	1032077.	2744110.	6799849.
50000. - 79999.	4391.	1048928.	219163.	1268092.	4548789.	10641460.
80000. - 99999.	291.	78642.	18644.	97287.	403519.	911153.
100000. - 149999.	99.	31170.	8538.	39709.	185832.	408017.
150000. - 199999.	20.	7472.	2226.	9698.	51211.	109932.
200000. - 300000.	7.	3245.	487.	3732.	27780.	58341.
TOTAL	29977.	5994691.	1939773.	7934464.	17171369.	44646969.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1990

ANALYZED BY MAIN SYSTEM

PREDICTED RESIDENTIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
7934464.	17171369.	44646969.

REQUIREMENTS BY TYPE - ANNUAL AVERAGE

TYPE	NO. OF UNITS	GALLONS PER DAY DOMESTIC	SPRINKLING	TOTAL
METERED AND SEWERED AREAS	29977.	5994691.	1939773.	7934464.
TOTAL	29977.	5994691.	1939773.	7934464.

SUMMER EVAPOTRANSPIRATION (INCHES) = 16.25

SUMMER PRECIPITATION (INCHES) = 7.75

MAX. DAY EVAPOTRANSPIRATION (INCHES) = .29

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1990

ANALYZED BY MAIN SYSTEM

TOTAL COMMERCIAL REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
2857311.	4760123.	11073956.

WATER REQUIREMENTS BY TYPE OF COMMERCIAL ESTABLISHMENT

TYPE	UNITS	NUMBER OF UNITS	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
			(GALLONS	PER DAY	)
HOTELS	SQ. FT.	77704.	19892.	22845.	33646.
MOTELS	SQ. FT.	75572.	16928.	34839.	117136.
BARBER SHOPS	BARBER CHAIR	53.	2872.	4224.	20461.
BEAUTY SHOPS	STATION	231.	62037.	73644.	246766.
RESTAURANTS	SEAT	5234.	126664.	436521.	874089.
NIGHT CLUBS	PERSON SERVED	5620.	7474.	7474.	7474.
HOSPITALS	BED	458.	158585.	252545.	418006.
NURSING HOMES	BED	293.	38925.	42729.	124090.
MEDICAL OFFICES	SQ. FT.	159247.	98415.	264351.	791460.
LAUNDRY	SQ. FT.	9300.	2353.	3032.	14600.
LAUNDROMATS	SQ. FT.	8807.	19111.	41746.	57334.
RETAIL SPACE	SALES SQ. FT.	1052109.	111524.	162025.	265122.
SCHOOL,ELEM.	STUDENT	11545.	62112.	111756.	566850.
SCHOOL, HIGH	STUDENT	14469.	95929.	283592.	1750749.
BUS-RAIL DEPOTS	SQ. FT.	1037.	3455.	6743.	25936.
CAR WASHES	INSIDE SQ. FT.	9174.	43351.	94491.	288977.
CHURCHES	MEMBER	30317.	4184.	26133.	142491.
GOLF-SWIM CLUBS	MEMBER	588.	18225.	13051.	13051.
BOWLING ALLEYS	ALLEY	17.	2208.	2208.	2208.
COLLEGES RESID.	STUDENT	885.	93768.	100845.	221151.
NEW OFFICE BLDG.	SQ. FT.	313374.	29144.	54214.	163268.
OLD OFFICE BLDG.	SQ. FT.	453160.	64349.	36706.	160419.
THEATERS	SEAT	415.	1382.	1382.	1382.
SERVICE STATIONS	INSIDE SQ. FT.	37655.	9452.	22217.	1186148.
APARTMENTS	OCCUPIED UNITS	7983.	1732283.	2594433.	3464565.
FAST FOOD REST.	ESTABLISHMENT	18.	32189.	64378.	96566.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1990

ANALYZED BY MAIN SYSTEM

TOTAL INDUSTRIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
11774668.	11774668.	11774668.

REQUIREMENTS BY TYPE OF INDUSTRY

CODE	INDUSTRY CATEGORY	NUMBER OF EMPLOYEES	GALLONS/DAY ANNUAL AVERAGE	MAXIMUM DAY	PEAK HOUR
201	MEAT PRODUCTS	35.	31719.	31719.	31719.
230	WHL.APPAREL IND.	52.	1047.	1047.	1047.
249	MISCELL. WOOD	14.	2062.	2062.	2062.
264	PAPER PRODUCTS	125.	54442.	54442.	54442.
270	WHOL.PRINT IND.	55.	830.	830.	830.
281	BASIC CHEMICALS	434.	1190458.	1190458.	1190458.
282	FIBERS, PLASTICS	67.	57719.	57719.	57719.
284	SOAP-TOILET GOOD	96.	64283.	64283.	64283.
291	PETROLEUM REFIN.	2638.	8287021.	8287021.	8287021.
295	PAVING-ROOFING	8.	6459.	6459.	6459.
327	CEMENT-PLASTER	150.	53235.	53235.	53235.
329	NONMETALLIC MNRL	100.	44094.	44094.	44094.
336	NONFERROUS FOUND	25.	24679.	24679.	24679.
339	PRIME METAL IND.	182.	90602.	90602.	90602.
343	PLUMBING,HEATING	12.	4989.	4989.	4989.
344	STRUCTURE METAL	173.	55249.	55249.	55249.
346	METAL STAMPINGS	13.	6176.	6176.	6176.
347	METAL SERVICES	3.	5474.	5474.	5474.
349	FABRICATED METAL	224.	60809.	60809.	60809.
354	METALWORK.MACHRY	147.	28852.	28852.	28852.
355	SPECL INDUS.MACH	170.	49417.	49417.	49417.
356	GENRL IND. MACH.	46.	11398.	11398.	11398.
358	SERV. IND. MACH.	95.	31585.	31585.	31585.
359	MISCELL. MACHINE	221.	52668.	52668.	52668.
362	ELECT.IND.APPART	53.	17642.	17642.	17642.
366	COMMUNICATION EQ	59.	5073.	5073.	5073.
371	MOTOR VEHICLES	52.	16551.	16551.	16551.
373	SHIP & BOAT BLDG	2090.	347160.	347160.	347160.
391	JEWELRY, SILVER	3207.	982952.	982952.	982952.
399	MISCEL. MANUFACT	736.	190022.	190022.	190022.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 1990

ANALYZED BY MAIN SYSTEM

TOTAL PUBLIC-UNACCOUNTED REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
2098219.	2098219.	2098219.

REQUIREMENTS BY TYPE OF PUBLIC-UNACCOUNTED USAGE IN GALLONS PER DAY

TYPE	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
DISTRIB. LOSSES	1555396.	1555396.	1555396.
FREE SERVICES	542823.	542823.	542823.

SUMMARY OF MUNICIPAL WATER REQUIREMENTS FOR CITY OF LEVEL 4 DATA STUDY

ESTIMATED WATER REQUIREMENTS FOR YEAR 1990.
(ALL VALUES IN GALLONS PER DAY)

	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
MUNICIPAL	24664661.	33901566.	61377167.
RESIDENTIAL	7934464.	17171369.	44646969.
COMMERCIAL	2857311.	4760123.	11073956.
INDUSTRIAL	11774668.	11774668.	11774668.
PUBLIC AND UNACC.	2098219.	2098219.	2098219.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2000

ANALYZED BY MAIN SYSTEM

PREDICTED RESIDENTIAL WATER REQUIREMENTS BY CATEGORY

METERED AND SEWERED AREAS

VALUE RANGE ($)	NO. OF UNITS	DOMESTIC	ANNUAL AVERAGE SPRINKLING	TOTAL	MAX DAY	PEAK HOUR
5000. - 9999.	1518.	253954.	37428.	291382.	366928.	1247264.
10000. - 14999.	1740.	301818.	79375.	381193.	514006.	1617861.
15000. - 19999.	2742.	492791.	176634.	669425.	960100.	2852432.
20000. - 24999.	2712.	504207.	212810.	717016.	1102828.	3130132.
25000. - 29999.	6049.	1162491.	461998.	1624488.	2850290.	7769566.
30000. - 34999.	4492.	891186.	382488.	1273675.	2384707.	6310288.
35000. - 39999.	3012.	616394.	225521.	841915.	1819377.	4675803.
40000. - 49999.	4720.	1010022.	276320.	1286342.	3420154.	8475073.
50000. - 79999.	3541.	845860.	176734.	1022594.	3668160.	8581311.
80000. - 99999.	235.	63418.	15035.	78452.	325399.	734769.
100000. - 149999.	80.	25136.	6885.	32021.	149856.	329026.
150000. - 199999.	16.	6026.	1795.	7820.	41297.	88649.
200000. - 300000.	6.	2617.	393.	3010.	22402.	47046.
TOTAL	30864.	6175918.	2053415.	8229333.	17625505.	45859220.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2000

ANALYZED BY MAIN SYSTEM

PREDICTED RESIDENTIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
8229333.	17625505.	45859220.

REQUIREMENTS BY TYPE - ANNUAL AVERAGE

TYPE	NO. OF UNITS	GALLONS PER DAY DOMESTIC	SPRINKLING	TOTAL
METERED AND SEWERED AREAS	30864.	6175918.	2053415.	8229333.
TOTAL	30864.	6175918.	2053415.	8229333.

SUMMER EVAPOTRANSPIRATION (INCHES) = 16.25

SUMMER PRECIPITATION (INCHES) = 7.75

MAX. DAY EVAPOTRANSPIRATION (INCHES) = .29

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2000

ANALYZED BY MAIN SYSTEM

TOTAL COMMERCIAL REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
2911957.	4918039.	11309371.

WATER REQUIREMENTS BY TYPE OF COMMERCIAL ESTABLISHMENT

TYPE	UNITS	NUMBER OF UNITS	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
			(GALLONS	PER DAY	)
HOTELS	SQ. FT.	40083.	10261.	11784.	17355.
MOTELS	SQ. FT.	38933.	8732.	17971.	60424.
BARBER SHOPS	BARBER CHAIR	59.	3235.	4758.	23048.
BEAUTY SHOPS	STATION	260.	69884.	85211.	277976.
RESTAURANTS	SEAT	7229.	174938.	602385.	1207217.
NIGHT CLUBS	PERSON SERVED	7762.	10323.	10323.	10323.
HOSPITALS	BED	479.	165816.	264059.	437063.
NURSING HOMES	BED	306.	40699.	44677.	129748.
MEDICAL OFFICES	SQ. FT.	166508.	102902.	276403.	827544.
RETAIL SPACE	SALES SQ. FT.	1022934.	108436.	157339.	277229.
SCHOOL,ELEM.	STUDENT	11201.	60261.	108426.	549969.
SCHOOL, HIGH	STUDENT	13883.	92044.	272107.	1679343.
BUS-RAIL DEPOTS	SQ. FT.	1029.	3425.	6683.	25716.
CAR WASHES	INSIDE SQ. FT.	9096.	43479.	93689.	286524.
CHURCHES	MEMBER	30060.	4148.	25912.	141281.
GOLF-SWIM CLUBS	MEMBER	583.	18070.	12940.	12940.
BOWLING ALLEYS	ALLEY	16.	2189.	2189.	2189.
COLLEGES RESID.	STUDENT	877.	92972.	99989.	219274.
NEW OFFICE BLDG.	SQ. FT.	310714.	28896.	53753.	161882.
OLD OFFICE BLDG.	SQ. FT.	449314.	63803.	36394.	159657.
THEATERS	SEAT	411.	1370.	1370.	1370.
SERVICE STATIONS	INSIDE SQ. FT.	37336.	9371.	22028.	1176080.
APARTMENTS	OCCUPIED UNITS	8133.	1764735.	2643112.	3529571.
FAST FOOD REST.	ESTABLISHMENT	18.	31916.	63831.	95747.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2000

ANALYZED BY MAIN SYSTEM

TOTAL INDUSTRIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
12412135.	12412135.	12412135.

REQUIREMENTS BY TYPE OF INDUSTRY

			GALLONS/DAY		
CODE	INDUSTRY CATEGORY	NUMBER OF EMPLOYEES	ANNUAL AVERAGE	MAXIMUM DAY	PEAK HOUR
230	WHL.APPAREL IND.	35.	708.	708.	708.
281	BASIC CHEMICALS	472.	1296012.	1296012.	1296012.
282	FIBERS, PLASTICS	73.	62836.	62836.	62836.
284	SOAP-TOILET GOOD	104.	69983.	69983.	69983.
291	PETROLEUM REFIN.	2872.	9021805.	9021805.	9021805.
295	PAVING-ROOFING	8.	7032.	7032.	7032.
327	CEMENT-PLASTER	211.	74503.	74503.	74503.
329	NONMETALLIC MNRL	140.	61711.	61711.	61711.
336	NONFERROUS FOUND	8.	7724.	7724.	7724.
339	PRIME METAL IND.	57.	28358.	28358.	28358.
343	PLUMBING,HEATING	4.	1561.	1561.	1561.
344	STRUCTURE METAL	54.	17293.	17293.	17293.
346	METAL STAMPINGS	4.	1933.	1933.	1933.
347	METAL SERVICES	1.	1713.	1713.	1713.
349	FABRICATED METAL	70.	19033.	19033.	19033.
354	METALWORK.MACHRY	224.	44014.	44014.	44014.
355	SPECL INDUS.MACH	260.	75386.	75386.	75386.
356	GENRL IND. MACH.	70.	17388.	17338.	17388.
358	SERV. IND. MACH.	144.	48183.	48183.	48183.
359	MISCELL. MACHINE	336.	80346.	80346.	80346.
362	ELECT.IND.APPART	80.	26913.	26913.	26913.
366	COMMUNICATION EQ	90.	7739.	7739.	7739.
371	MOTOR VEHICLES	51.	16297.	16297.	16297.
373	SHIP & BOAT BLDG	2058.	341821.	341821.	341821.
391	JEWELRY, SILVER	2958.	906585.	906585.	906585.
399	MISCEL. MANUFACT	679.	175259.	175259.	175259.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2000

ANALYZED BY MAIN SYSTEM

TOTAL PUBLIC-UNACCOUNTED REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
2116369.	2116369.	2116369.

REQUIREMENTS BY TYPE OF PUBLIC-UNACCOUNTED USAGE IN GALLONS PER DAY

TYPE	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
DISTRIB. LOSSES	1568851.	1568851.	1568851.
FREE SERVICES	547518.	547518.	547518.

SUMMARY OF MUNICIPAL WATER REQUIREMENTS FOR CITY OF LEVEL 4 DATA STUDY

ESTIMATED WATER REQUIREMENTS FOR YEAR 2000.
(ALL VALUES IN GALLONS PER DAY)

	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
MUNICIPAL	25669795.	35065966.	63299681.
RESIDENTIAL	8229333.	17625505.	45859220.
COMMERCIAL	2911957.	4918039.	11309371.
INDUSTRIAL	12412135.	12412135.	12412135.
PUBLIC AND UNACC.	2116369.	2116369.	2116369.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2010

ANALYZED BY MAIN SYSTEM

PREDICTED RESIDENTIAL WATER REQUIREMENTS BY CATEGORY

METERED AND SEWERED AREAS

		ANNUAL AVERAGE				
VALUE RANGE ($)	NO. OF UNITS	DOMESTIC	SPRINKLING	TOTAL	MAX DAY	PEAK HOUR
5000. - 9999.	1204.	201366.	29677.	231043.	290946.	988982.
10000. - 14999.	1380.	239318.	62938.	302256.	407566.	1282837.
15000. - 19999.	2174.	390745.	140057.	530801.	761284.	2261755.
20000. - 24999.	2150.	399797.	168741.	568538.	874456.	2481949.
25000. - 29999.	7457.	1432933.	569477.	2002410.	3513383.	9577081.
30000. - 34999.	5537.	1098512.	471470.	1569983.	2939487.	7778316.
35000. - 39999.	3713.	759792.	277986.	1037778.	2242638.	5763584.
40000. - 49999.	5819.	1244993.	340603.	1585597.	4215820.	10446718.
50000. - 79999.	2708.	646863.	135156.	782018.	2805189.	6562473.
80000. - 99999.	180.	48498.	11493.	59996.	248846.	561907.
100000. - 149999.	61.	19222.	5265.	24438.	114601.	251619.
150000. - 199999.	12.	4608.	1373.	5981.	31581.	67794.
200000. - 300000.	4.	2001.	301.	2302.	17131.	35978.
TOTAL	32399.	6488648.	2214543.	8703191.	18462929.	48060993.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2010

ANALYZED BY MAIN SYSTEM

PREDICTED RESIDENTIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
8703191.	18462929.	48060993.

REQUIREMENTS BY TYPE - ANNUAL AVERAGE

TYPE	NO. OF UNITS	GALLONS PER DAY DOMESTIC	SPRINKLING	TOTAL
METERED AND SEWERED AREAS	32399.	6488648.	2214543.	8703191.
TOTAL	32399.	6488648.	2214543.	8703191.

SUMMER EVAPOTRANSPIRATION (INCHES) = 16.25

SUMMER PRECIPITATION (INCHES) = 7.75

MAX. DAY EVAPOTRANSPIRATION (INCHES) = .29

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2010

ANALYZED BY MAIN SYSTEM

TOTAL COMMERCIAL REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
2977101.	5099191.	11593711.

WATER REQUIREMENTS BY TYPE OF COMMERCIAL ESTABLISHMENT

TYPE	UNITS	NUMBER OF UNITS	ANNUAL AVERAGE (GALLONS PER DAY)	MAXIMUM DAILY	PEAK HOURLY
HOTELS	SQ. FT.	2556.	654.	752.	1107.
MOTELS	SQ. FT.	2486.	557.	1146.	3854.
BARBER SHOPS	BARBER CHAIR	65.	3575.	5258.	25471.
BEAUTY SHOPS	STATION	287.	77229.	94167.	307192.
RESTAURANTS	SEAT	9096.	220124.	758610.	1519040.
NIGHT CLUBS	PERSON SERVED	9766.	12989.	12989.	12989.
HOSPITALS	BED	500.	172881.	275310.	455686.
NURSING HOMES	BED	319.	42433.	46581.	135276.
MEDICAL OFFICES	SQ. FT.	173602.	107286.	288180.	862804.
RETAIL SPACE	SALES SQ. FT.	995040.	105474.	153236.	269656.
SCHOOL, ELEM.	STUDENT	11130.	59879.	107738.	546483.
SCHOOL, HIGH	STUDENT	13335.	88411.	261366.	1613535.
BUS-RAIL DEPOTS	SQ. FT.	1020.	3398.	6633.	25512.
CAR WASHES	INSIDE SQ. FT.	9024.	43133.	92944.	284246.
CHURCHES	MEMBER	29821.	4115.	25706.	140153.
GOLF-SWIM CLUBS	MEMBER	578.	17926.	12838.	12838.
BOWLING ALLEYS	ALLEY	16.	2172.	2172.	2172.
COLLEGES RESID.	STUDENT	870.	92233.	99194.	217531.
NEW OFFICE BLDG.	SQ. FT.	308244.	28667.	53326.	160595.
OLD OFFICE BLDG.	SQ. FT.	445742.	63295.	36105.	157793.
THEATERS	SEAT	408.	1359.	1359.	1359.
SERVICE STATIONS	INSIDE SQ. FT.	37039.	9297.	21853.	1166730.
APARTMENTS	OCCUPIED UNITS	8241.	1788350.	2678404.	3576699.
FAST FOOD REST.	ESTABLISHMENT	18.	31662.	63324.	94986.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2010

ANALYZED BY MAIN SYSTEM

TOTAL INDUSTRIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
13178736.	13178736.	13178736.

REQUIREMENTS BY TYPE OF INDUSTRY

			GALLONS/DAY		
CODE	INDUSTRY CATEGORY	NUMBER OF EMPLOYEES	ANNUAL AVERAGE	MAXIMUM DAY	PEAK HOUR
230	WHL.APPAREL IND.	18.	361.	361.	361.
281	BASIC CHEMICALS	509.	1396171.	1396171.	1396171.
282	FIBERS, PLASTICS	78.	67692.	67692.	67692.
284	SOAP-TOILET GOOD	112.	75391.	75391.	75391.
291	PETROLEUM REFIN.	3094.	9719028.	9719028.	9719028.
295	PAVING-ROOFING	9.	7575.	7575.	7575.
327	CEMENT-PLASTER	270.	95647.	95647.	95647.
329	NONMETALLIC MNRL	180.	79224.	79224.	79224.
354	METALWORK.MACHRY	301.	59133.	59133.	59133.
355	SPECL INDUS.MACH	349.	101283.	101283.	101283.
356	GENRL IND. MACH.	95.	23361.	23361.	23361.
358	SERV. IND. MACH.	194.	64734.	64734.	64734.
359	MISCELL. MACHINE	452.	107946.	107946.	107946.
362	ELECT.IND.APPART	108.	36159.	36159.	36159.
366	COMMUNICATION EQ	121.	10398.	10398.	10398.
371	MOTOR VEHICLES	50.	15955.	15955.	15955.
373	SHIP & BOAT BLDG	2015.	334655.	334655.	334655.
391	JEWELRY, SILVER	2690.	824611.	824611.	824611.
399	MISCEL. MANUFACT	617.	159412.	159412.	159412.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2010

ANALYZED BY MAIN SYSTEM

TOTAL PUBLIC-UNACCOUNTED REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
2123826.	2123826.	2123826.

REQUIREMENTS BY TYPE OF PUBLIC-UNACCOUNTED USAGE IN GALLONS PER DAY

TYPE	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
DISTRIB. LOSSES	1574379.	1574379.	1574379.
FREE SERVICES	549448.	549448.	549448.

SUMMARY OF MUNICIPAL WATER REQUIREMENTS FOR CITY OF LEVEL 4 DATA STUDY

ESTIMATED WATER REQUIREMENTS FOR YEAR 2010.
(ALL VALUES IN GALLONS PER DAY)

	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
MUNICIPAL	26982854.	36742592.	66340657.
RESIDENTIAL	8703191.	18462929.	48060993.
COMMERCIAL	2977101.	5099191.	11593711.
INDUSTRIAL	13178736.	13178736.	13178736.
PUBLIC AND UNACC.	2123826.	2123826.	2123826.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2020

ANALYZED BY MAIN SYSTEM

PREDICTED RESIDENTIAL WATER REQUIREMENTS BY CATEGORY

METERED AND SEWERED AREAS

VALUE RANGE ($)	NO. OF UNITS	ANNUAL AVERAGE DOMESTIC	ANNUAL AVERAGE SPRINKLING	ANNUAL AVERAGE TOTAL	MAX DAY	PEAK HOUR
5000. - 9999.	827.	138292.	20382.	158674.	199813.	679206.
10000. - 14999.	947.	164357.	43224.	207581.	279905.	881017.
15000. - 19999.	1493.	268353.	96187.	364540.	522829.	1553311.
20000. - 24999.	1477.	274569.	115887.	390456.	600552.	1704534.
25000. - 29999.	8796.	1690315.	671766.	2362081.	4144453.	11297305.
30000. - 34999.	6532.	1295826.	556155.	1851981.	3467474.	9175449.
35000. - 39999.	4380.	896265.	327918.	1224183.	2645458.	6798832.
40000. - 49999.	6864.	1468618.	401782.	1870400.	4973061.	12323145.
50000. - 79999.	1781.	425399.	88883.	514282.	1844790.	4315709.
80000. - 99999.	118.	31894.	7561.	39455.	163650.	369530.
100000. - 149999.	40.	12641.	3463.	16104.	75365.	165474.
150000. - 199999.	8.	3030.	903.	3933.	20769.	44583.
200000. - 300000.	3.	1316.	198.	1514.	11266.	23660.
TOTAL	33266.	6670875.	2334309.	9005184.	18949386.	49331755.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2020

ANALYZED BY MAIN SYSTEM

PREDICTED RESIDENTIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
9005184.	18949386.	49331755.

REQUIREMENTS BY TYPE - ANNUAL AVERAGE

TYPE	NO. OF UNITS	GALLONS PER DAY DOMESTIC	SPRINKLING	TOTAL
METERED AND SEWERED AREAS	33266.	6670875.	2334309.	9005184.
TOTAL	33266.	6670875.	2334309.	9005184.

SUMMER EVAPOTRANSPIRATION (INCHES) = 16.25

SUMMER PRECIPITATION (INCHES) = 7.75

MAX. DAY EVAPOTRANSPIRATION (INCHES) = .29

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2020

ANALYZED BY MAIN SYSTEM

TOTAL COMMERCIAL REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
3059631.	5304234.	11950574.

WATER REQUIREMENTS BY TYPE OF COMMERCIAL ESTABLISHMENT

TYPE	UNITS	NUMBER OF UNITS	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
			(GALLONS	PER DAY	)
BARBER SHOPS	BARBER CHAIR	71.	3901.	5737.	27794.
BEAUTY SHOPS	STATION	313.	84272.	102755.	335208.
RESTAURANTS	SEAT	10868.	263016.	906426.	1815025.
NIGHT CLUBS	PERSON SERVED	11669.	15520.	15520.	15520.
HOSPITALS	BED	520.	179763.	286270.	473825.
NURSING HOMES	BED	332.	44122.	48435.	140661.
MEDICAL OFFICES	SQ. FT.	180513.	111557.	299652.	897150.
RETAIL SPACE	SALES SQ. FT.	970610.	102885.	149474.	263035.
SCHOOL,ELEM.	STUDENT	10957.	58949.	106064.	537989.
SCHOOL, HIGH	STUDENT	12933.	35746.	253487.	1564893.
BUS-RAIL DEPOTS	SQ. FT.	1015.	3378.	6594.	25363.
CAR WASHES	INSIDE SQ. FT.	8971.	42882.	92402.	282589.
CHURCHES	MEMBER	29647.	4091.	25556.	139341.
GOLF-SWIM CLUBS	MEMBER	575.	17822.	12763.	12763.
BOWLING ALLEYS	ALLEY	16.	2159.	2159.	2159.
COLLEGES RESID.	STUDENT	865.	91695.	98616.	216263.
NEW OFFICE BLDG.	SQ. FT.	306447.	28500.	53015.	159559.
OLD OFFICE BLDG.	SQ. FT.	443144.	62926.	35895.	156873.
THEATERS	SEAT	406.	1351.	1351.	1351.
SERVICE STATIONS	INSIDE SQ. FT.	36823.	9243.	21726.	1159929.
APARTMENTS	OCCUPIED UNITS	8361.	1814376.	2717383.	3628751.
FAST FOOD REST.	ESTABLISHMENT	18.	31477.	62955.	94432.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2020

ANALYZED BY MAIN SYSTEM

TOTAL INDUSTRIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
14043922.	14043922.	14043922.

REQUIREMENTS BY TYPE OF INDUSTRY

			GALLONS/DAY		
CODE	INDUSTRY CATEGORY	NUMBER OF EMPLOYEES	ANNUAL AVERAGE	MAXIMUM DAY	PEAK HOUR
230	WHL.APPAREL IND.	1.	12.	12.	12.
281	BASIC CHEMICALS	546.	1498638.	1498638.	1498638.
282	FIBERS, PLASTICS	84.	72660.	72660.	72660.
284	SOAP-TOILET GOOD	120.	80925.	80925.	80925.
291	PETROLEUM REFIN.	3321.	10432325.	10432325.	10432325.
295	PAVING-ROOFING	10.	8131.	8131.	8131.
327	CEMENT-PLASTER	331.	117065.	117065.	117065.
329	NONMETALLIC MNRL	221.	96965.	96965.	96965.
354	METALWORK.MACHRY	379.	74439.	74439.	74439.
355	SPECL INDUS.MACH	439.	127499.	127499.	127499.
356	GENRL IND. MACH.	119.	29407.	29407.	29407.
358	SERV. IND. MACH.	244.	81490.	81490.	81490.
359	MISCELL. MACHINE	569.	135887.	135887.	135887.
362	ELECT.IND.APPART	135.	45518.	45518.	45518.
366	COMMUNICATION EQ	152.	13089.	13089.	13089.
371	MOTOR VEHICLES	49.	15628.	15628.	15628.
373	SHIP & BOAT BLDG	1974.	327787.	327787.	327787.
391	JEWELRY, SILVER	2424.	742851.	742851.	742851.
399	MISCEL. MANUFACT	556.	143606.	143606.	143606.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2020

ANALYZED BY MAIN SYSTEM

TOTAL PUBLIC-UNACCOUNTED REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
2133615.	2133615.	2133615.

REQUIREMENTS BY TYPE OF PUBLIC-UNACCOUNTED USAGE IN GALLONS PER DAY

TYPE	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
DISTRIB. LOSSES	1581635.	1581635.	1581635.
FREE SERVICES	551980.	551980.	551980.

SUMMARY OF MUNICIPAL WATER REQUIREMENTS FOR CITY OF LEVEL 4 DATA STUDY

ESTIMATED WATER REQUIREMENTS FOR YEAR 2020.
(ALL VALUES IN GALLONS PER DAY)

	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
MUNICIPAL	28242352.	38186554.	68568924.
RESIDENTIAL	9005184.	18949386.	49331755.
COMMERCIAL	3059631.	5304234.	11950574.
INDUSTRIAL	14043922.	14043922.	14043922.
PUBLIC AND UNACC.	2133615.	2133615.	2133615.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2030

ANALYZED BY MAIN SYSTEM

PREDICTED RESIDENTIAL WATER REQUIREMENTS BY CATEGORY

METERED AND SEWERED AREAS

VALUE RANGE ($)	NO. OF UNITS	ANNUAL AVERAGE DOMESTIC	ANNUAL AVERAGE SPRINKLING	ANNUAL AVERAGE TOTAL	MAX DAY	PEAK HOUR
5000. - 9999.	418.	69953.	10310.	80263.	101072.	343565.
10000. - 14999.	479.	83137.	21864.	105002.	141586.	445648.
15000. - 19999.	755.	135742.	48655.	184397.	264455.	785717.
20000. - 24999.	747.	138886.	58620.	197506.	303780.	862211.
25000. - 29999.	10223.	1964427.	780704.	2745131.	4816543.	13129347.
30000. - 34999.	7591.	1505965.	646345.	2152310.	4029781.	10663398.
35000. - 39999.	5090.	1041609.	381095.	1422704.	3074462.	7901374.
40000. - 49999.	7977.	1706778.	466938.	2173716.	5779524.	14321544.
50000. - 79999.	849.	202772.	42367.	245139.	879341.	2057135.
80000. - 99999.	56.	15203.	3604.	18807.	78006.	176141.
100000. - 149999.	19.	6026.	1651.	7676.	35924.	78875.
150000. - 199999.	4.	1445.	430.	1875.	9900.	21251.
200000. - 300000.	1.	627.	94.	722.	5370.	11278.
TOTAL	34210.	6872569.	2462676.	9335245.	19519754.	50797484.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2030

ANALYZED BY MAIN SYSTEM

PREDICTED RESIDENTIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
9335245.	19519754.	50797484.

REQUIREMENTS BY TYPE - ANNUAL AVERAGE

TYPE	NO. OF UNITS	GALLONS PER DAY DOMESTIC	SPRINKLING	TOTAL
METERED AND SEWERED AREAS	34210.	6872569.	2462676.	9335245.
TOTAL	34210.	6872569.	2462676.	9335245.

SUMMER EVAPOTRANSPIRATION (INCHES) = 16.25

SUMMER PRECIPITATION (INCHES) = 7.75

MAX. DAY EVAPOTRANSPIRATION (INCHES) = .29

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2030

ANALYZED BY MAIN SYSTEM

TOTAL COMMERCIAL REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
3128338.	5487609.	12310889.

WATER REQUIREMENTS BY TYPE OF COMMERCIAL ESTABLISHMENT

TYPE	UNITS	NUMBER OF UNITS	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
			(GALLONS	PER	DAY)
BARBER SHOPS	BARBER CHAIR	77.	4213.	6197.	30018.
BEAUTY SHOPS	STATION	338.	91017.	110979.	362036.
RESTAURANTS	SEAT	12555.	303843.	1047127.	2096765.
NIGHT CLUBS	PERSON SERVED	13481.	17930.	17930.	17930.
HOSPITALS	BED	539.	186496.	296993.	491574.
NURSING HOMES	BED	344.	45775.	50250.	145930.
MEDICAL OFFICES	SQ. FT.	187275.	115736.	310876.	930756.
RETAIL SPACE	SALES SQ. FT.	948338.	100524.	146044.	256999.
SCHOOL, ELEM.	STUDENT	10998.	59169.	106461.	540002.
SCHOOL, HIGH	STUDENT	12804.	84391.	250958.	1549234.
BUS-RAIL DEPOTS	SQ. FT.	1010.	3363.	6564.	25247.
CAR WASHES	INSIDE SQ. FT.	8930.	42686.	91981.	281301.
CHURCHES	MEMBER	29512.	4073.	25439.	138706.
COLF-SWIM CLUBS	MEMBER	572.	17741.	12705.	12705.
BOWLING ALLEYS	ALLEY	16.	2149.	2149.	2149.
COLLEGES RESID.	STUDENT	861.	91277.	98166.	215276.
NEW OFFICE BLDG.	SQ. FT.	305050.	28370.	52774.	153931.
OLD OFFICE BLDG.	SQ. FT.	441123.	62640.	35731.	156158.
THEATERS	SEAT	404.	1345.	1345.	1345.
SERVICE STATIONS	INSIDE SQ. FT.	36655.	9200.	21627.	1154640.
APARTMENTS	OCCUPIED UNITS	8408.	1824567.	2732647.	3649135.
FAST FOOD REST.	ESTABLISHMENT	18.	31334.	62668.	94001.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2030

ANALYZED BY MAIN SYSTEM

TOTAL INDUSTRIAL WATER REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
14903962.	14903962.	14903962.

REQUIREMENTS BY TYPE OF INDUSTRY

			GALLONS/DAY		
CODE	INDUSTRY CATEGORY	NUMBER OF EMPLOYEES	ANNUAL AVERAGE	MAXIMUM DAY	PEAK HOUR
281	BASIC CHEMICALS	583.	1600605.	1600605.	1600605.
282	FIBERS, PLASTICS	90.	77604.	77604.	77604.
284	SOAP-TOILET GOOD	129.	86431.	86431.	86431.
291	PETROLEUM REFIN.	3547.	11142135.	11142135.	11142135.
295	PAVING-ROOFING	10.	8684.	8684.	8684.
327	CEMENT-PLASTER	392.	138556.	138556.	138556.
329	NONMETALLIC MNRL	261.	114766.	114766.	114766.
354	METALWORK.MACHRY	458.	89806.	89806.	89806.
355	SPECL INDUS.MACH	530.	153818.	153818.	153818.
356	GENRL IND. MACH.	144.	35478.	35478.	35478.
358	SERV. IND. MACH.	294.	98312.	98312.	98312.
359	MISCELL. MACHINE	686.	163938.	163938.	163938.
362	ELECT.IND.APPART	163.	54914.	54914.	54914.
366	COMMUNICATION EQ	183.	15791.	15791.	15791.
371	MOTOR VEHICLES	48.	15283.	15283.	15283.
373	SHIP & BOAT BLDG	1930.	320566.	320566.	320566.
391	JEWELRY, SILVER	2153.	659736.	659736.	659736.
399	MISCEL. MANUFACT	494.	127539.	127539.	127539.

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF LEVEL 4 DATA STUDY FOR THE YEAR 2030

ANALYZED BY MAIN SYSTEM

TOTAL PUBLIC-UNACCOUNTED REQUIREMENTS IN GALLONS PER DAY

ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
2141555.	2141555.	2141555.

REQUIREMENTS BY TYPE OF PUBLIC-UNACCOUNTED USAGE IN GALLONS PER DAY

TYPE	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
DISTRIB. LOSSES	1587521.	1587521.	1587521.
FREE SERVICES	554034.	554034.	554034.

SUMMARY OF MUNICIPAL WATER REQUIREMENTS FOR CITY OF LEVEL 4 DATA STUDY

ESTIMATED WATER REQUIREMENTS FOR YEAR 2030.
(ALL VALUES IN GALLONS PER DAY)

	ANNUAL AVERAGE	MAXIMUM DAILY	PEAK HOURLY
MUNICIPAL	29509099.	39693608.	70971338.
RESIDENTIAL	9335245.	19519754.	50797484.
COMMERCIAL	3128338.	5487609.	12310889.
INDUSTRIAL	14903962.	14903962.	14903962.
PUBLIC AND UNACC.	2141555.	2141555.	2141555.

I W R   M A I N   S Y S T E M

SUMMARY OF PROJECTED MUNICIPAL WATER REQUIREMENTS

FOR CITY OF

LEVEL 4 DATA STUDY

RUN NO.	YEAR	GALLONS PER DAY MEAN ANNUAL	MAX DAY	PEAK HOUR
1	1980	23891889.	32798254.	59053914.
2	1990	24664661.	33901566.	61377167.
3	2000	25669795.	35065966.	63299681.
4	2010	26982854.	36742592.	66340657.
5	2020	28242352.	38186554.	68568924.
6	2030	29509099.	39693608.	70971338.

IX. EXAMPLE E — PROBABILISTIC FORECAST

Background and Approach

Example E is based on the same study area and data used in the Example C forecast (Section VII). The data collected for that forecast correspond generally to Level 3 (see Section II), and include estimates of sectoral water use obtained by sampling each major user group. The probabilistic forecast described here is based on the same forecasting method applied in Example C, although the contingency tree approach described can be used in conjunction with any forecasting method.

The contingency tree approach was first proposed for water use forecasting applications by Whitford (1972). Its purpose is to approximate the probability distribution of possible water use levels, so that probabilistic statements can be made concerning future water use. This is done by considering a range of outcomes for each of a number of uncertain factors or future conditions known to affect water use. A probability of occurrence is assigned to each discrete event (each alternative level of a particular factor, for example), and joint probabilities are calculated for all possible combinations of events. The original forecasting method is used to estimate future water use for each possible combination of events, and each water use level is associated with its corresponding probability. Accumulation of these results gives a probability distribution of future water use which incorporates the uncertainty attributed to all factors considered.

Data Collection

BASIC FORECAST DATA

All data required to produce a basic forecast of water use for the study area were collected as a part of the Example C forecast, and are described in Section VII. Water use data were obtained by sampling various user sectors, and are available for the following major sectors:

1. Residential
2. Commercial/Industrial
3. Institutional (military)
4. Public/unaccounted

The residential sector is further divided into single family residences (SFR) and multi-family residences (MFR). The commercial/industrial sector has two subsectors: (1) manufacturing firms with water use in excess of 50,000 gpd, and (2) all other firms. Projections were obtained or derived for population, number of households by household type (SFR or MFR), household size, employment, military personnel, and unaccounted water. These projections appear in Section VII as Tables VII-4, VII-6, VII-8, and VII-10.

PROBABILITY ESTIMATES

Residential Sector

Least squares linear regressions are derived (in Section VII) from the SFR and MFR data. The most significant regressions express water use for SFR's in terms of consumption per household and for MFR's in terms of consumption per capita (see Equations VII-1 and VII-2). Within each of the subsectors, a water conservation scenario is incorporated which allows for the replacement of conventional water taps and shower heads by water saving fixtures, giving modified equations VII-3 and VII-4.

Water use for the residential sector is stated as follows:

$$RESUSE = (SFHH_o \cdot QRES_o) + (SFHH_n \cdot QRES_n) + (MFPOP_o \cdot QPC_o) + (MFPOP_n \cdot QPC_n) \quad (IX-1)$$

Where: RESUSE = residential water use
SFHH = Number of single family households with old (o) or new (n) plumbing fixtures
QRES = water use per residence with old (o) or new (n) plumbing fixtures
MFPOP = population in multi-family residences with old (o) or new (n) plumbing fixtures
QPC = water use per capita with old (o) or new (n) plumbing fixtures in multi-family residences.

The sample data described in Section VII provide probability distributions for QRES and QPC with conventional plumbing fixtures. The same distributions, shifted to give a lower mean value, are assumed to apply in the case of water conserving fixtures. This quantitative information regarding the variability of QRES and QPC provides a basis for describing the variability of water use among similar households. Variability could also be assigned to SFHH and MFPOP, but these are assumed fixed for two reasons: (1) the sample data provides some measure of quantitative support for variation in QRES and QPC which is not available for the other variables, and (2) alternatives are implicit for household size. Furthermore, the concept of conservation through new fixtures need not be confined to one scenario (as in Example C), but is free to vary in effect over a range of water use reductions.

Three values are chosen for each of the two factors to be varied. These values are based on the mean of the sample data, plus or minus one standard deviation. The resulting assignment of alternatives yields 81 possible values of residential water use, although some values are considered to have negligible probability of occurrence. This number of alternatives can be reduced by two simplifying assumptions:

1. Within each subsector, the above average values for households with old fixtures will combine only with above average values for households with new fixtures, e.g., whatever societal norms of water use which influence one set of households will also influence the other in a similar manner. Thus, for SFR's the following combinations

$QRES_{o1} \rightarrow QRES_{n1}$
$QRES_{o2} \rightarrow QRES_{n2}$
$QRES_{o3} \rightarrow QRES_{n3}$

result in three alternatives, not nine. A similar combination format for QPC reduces the multi-family alternatives from nine to three.

2. The alternatives in each of the subsectors can combine in such a way that there is no more than one order of difference between them. Thus, the highest alternative value for SFR's can combine with the highest and the mean values of MFR's but not with the lowest MFR value. The resulting contingency tree indicates seven alternate values for the residential sector.

Residential Schematic Alternatives

QRES	QPC	COMBINATION NO.
Hi	Hi	1
	Mean	2
Mean	Hi	3
	Mean	4
	Lo	5
Lo	Mean	6
	Lo	7

The rationale for this assumption is again that societal norms in water use will be reasonably consistent between residential subsectors.

The "Lo" value for each coefficient is defined as the mean less one standard deviation (calculated from sample data); the "Hi" value is defined as the mean plus one standard deviation. Approximate probabilities are assigned as follows to each of the alternative values by analysis of the shape of the relevant frequency distribution of sample data.

	Lo	Mean	Hi
SFR: QRES probability, p =	0.25,	0.43,	0.32
MFR: QPC probability, p =	0.35,	0.53,	0.12

The resulting joint probabilities of values for residential sector are shown in the following contingency tree.

(Probability) QRES	(Probability) QPC	Joint Probability
(0.32) Hi	(0.12) Hi	0.0384
	(0.88) Mean	0.2816
(0.43) Mean	(0.12) Hi	0.0516
	(0.53) Mean	0.2279
	(0.35) Lo	0.1505

(Probability) QRES	(Probability) QPC	Joint Probability
(0.25) Lo	(0.65) Mean	0.1625
	(0.35) Lo	0.0875

Where, for Hi QRES combined with Lo QPC and Lo QRES combined with Hi QPC there is zero probability by the second simplifying assumption just mentioned.

Commercial/Industrial Sector

As in the Exampl. C forecast, the calculation of commercial and industrial water use is divided into two sub-sectors:

1. manufacturing firms (Standard Industrial Classifications (SIC) 2 and 3) using more than approximately 50,000 gpd; total 1975 base year usage was 1.18 mgd.
2. the remainder of manufacturing and all other commercial and industrial water usage; total base year usage was 7.76 mgd.

Forecasts of future water use are based upon projected changes in employment for each of the subsectors, e.g., if for some future year, employment is projected to increase by 25 percent over that in the base year, then water use is assumed to increase by the same percentage. The application of this algorithm to the whole forecast period implies constant water use per employee as the net result of water conservation and increased productivity.

The calculation of water use for the sector takes the form of the following expression:

$$\text{CIUSE} = \text{MANQ}_{75}\left(\frac{\text{MANEMP}_{yr}}{\text{MANEMP}_{75}}\right) + \text{REMQ}_{75}\left(\frac{\text{REMEMP}_{yr}}{\text{REMEMP}_{75}}\right) \qquad \text{(IX-2)}$$

Where: CIUSE = Commercial/Industrial water use
MANQ75 = manufacturing subsector water use in 1975
REMQ75 = remainder subsector water use in 1975
MANEMP = manufacturing employment in forecast year or 1975
REMEMP = remainder employment in forecast year or 1975.

Future employment appears to be the only factor suitable for statement in probabilistic terms. In fact, several alternate future employment projections are available for the study area. In this case, and as a general matter, confidence in any projection tends to decrease as the forecast period increases. Thus, the variability or the range associated with a given probability of some mean value may increase. In all forecast years the probability of high and low alternatives is assumed to be 25 percent, and for the example year the values of employment to which that probability is assigned are ±10 percent of the mean.

For each subsector, then, three alternatives for values are chosen (mean-10%, mean, mean + 10%) and each is combined with all three values for the other subsector which results in nine alternative values of water use for the sector, with the following probabilities of occurrence.

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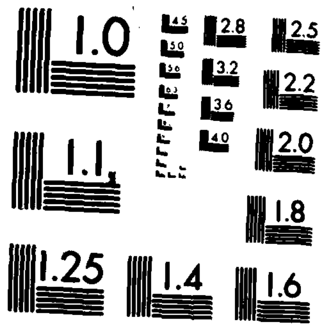

(Probability) Manufacturing Employment	(Probability) Remainder Employment	Joint Probability
	(0.25) Hi	0.0625
(0.25) Hi	(0.50) Mean	0.1250
	(0.25) Lo	0.0625
	(0.25) Hi	0.1250
(0.50) Mean	(0.50) Mean	0.2500
	(0.25) Lo	0.1250
	(0.25) Hi	0.0625
(0.25) Lo	(0.50) Mean	0.1250
	(0.25) Lo	0.0625

Institutional (Military) Sector

The institutional sector for this example consists entirely of a military base with its residents, and military and civilian employees. The water use is disaggregated into two subsectors: one attributed to residential use and the other designated as employee related use. The residential subsector is assumed to broadly follow the pattern of MFR water use, both in magnitude and in the shape of the probability distribution derived from the sample data. The employment subsector (since metered data are not available) is assumed to account for the remainder of usage. Per employee water use is estimated at 81 gpd and is assumed constant over the forecast period with a net zero balance between conservation and increasedemployee productivity. Base year and projected employment information are available. The calculation of water use for the sector takes the form of the following expression:

$$MILUSE = (MFRPC \cdot RESP) + (MILG \cdot EMPLOY) \qquad \text{(IX-3)}$$

Where: MILUSE = total water use for the military sector
MFRPC = multi-family per capita consumption
RESP = residential population on military base
MILG = employee water use per day
EMPLOY = number of employees at the military base

The high and low alternatives to the mean residential water use are chosen as plus or minus one standard error of estimate (30.2 gpcd) from the regression estimated with the residential data and the associated probabilities are the same as those for MFR in the residential sector.

Three alternative levels are chosen for military employment water usage with the following subjective probabilities:

Hi (mean + 50%)	p = 0.25
Mean	p = 0.50
Lo (mean - 50%)	p = 0.25

Thus, the military sector has nine alternative values of water usage with associated joint probabilities as shown in the following contingency tree.

(Probability) MFRPC	(Probability) MILG	Joint Probability
	(0.25) Hi	0.0300
(0.12) Hi	(0.50) Mean	0.0600
	(0.25) Lo	0.0300
	(0.25) Hi	0.1325
(0.53) Mean	(0.50) Mean	0.2650
	(0.25) Lo	0.1325
	(0.25) Hi	0.0875
(0.35) Lo	(0.50) Mean	0.1750
	(0.25) Lo	0.0875

Public/Unaccounted Sector

The fraction of unaccounted water use in the later years of the Example C forecast is 12.3 percent. One alternative to this projection is chosen; and in the light of practical experience elsewhere, it is selected to be 17 percent. For illustrative purposes, a subjective probability of occurrence of 0.5 is assigned to each of the alternatives.

Forecast

The assumption is made that the probabilities assigned to the alternatives in each of the sectors will remain constant for any year within the forecast period. The data and the assignment of probabilities have been discussed for each sector of water use, and the number of resulting alternatives is as follows:

	Number of Alternatives
Residential	7
Commercial/industrial	9
Institutional (Military)	9
Public/Unaccounted	2
Combined Total	1134

The occurrence of each of the alternatives in each of the sectors is assumed to be independent of all other events, therefore each alternative in one sector can combine with all the alternatives of the other sectors. The total number of alternative forecast values (1134) is the product of the numbers for the sectors. The probability of occurrence of each of the alternative forecast values is the joint probability (product of the marginal probabilities) of each of the contributing sector alternatives as shown in the following diagram:

Sector A	Sector B	Sector C	Sector D	Forecast
$p(a_1)$, a_1	$p(b_1)$, b_1	-	-	-
	$p(b_2)$, b_2	-	-	-
	$p(b_1)$, b_1	$p(c_1)$, c_1		
$p(a_2)$, a_2	$p(b_2)$, b_2	$p(c_2)$, c_2	$p(d_1)$, d_1	$p(F_i)$, F_i
			$p(d_2)$, d_2	
	$p(b_3)$, b_3	$p(c_3)$, c_3		
	$p(b_2)$, b_2			
	$p(b_3)$, b_3			

Where: $F_i = a_2, b_2, c_2, d_1$

$p(F_i) = p(a_2) \cdot p(b_2) \cdot p(c_2) \cdot p(d_1)$, and

$i = 1$ to 1134.

The order in which the sectors occur and are brought into the calculation of the forecast has no effect on the results.

A forecast for one future year (2000) is chosen for illustration, although forecasts could be determined for any year within the planning period. Water use is calculated for each combination of alternatives and weighted by the corresponding joint probability. The forecast consists of 1134 alternative values of water use whose descriptive statistics are:

	Average Day Water Use (mgd)
mean	39.31
standard deviation	6.00
median	39.28
skewness	0.031
minimum	25.5
maximum	53.9

The range of values of the forecast is approximately 29 mgd and if the individual probabilities of the 1134 values are accumulated for 1 mgd increments, a fairly smooth, normally distributed probability mass diagram (histogram) of water use can be drawn (Figure IX-1). The choice of an increment smaller than 1 mgd would result in a smoother histogram. The cumulative probability distribution function for the forecast is plotted as Figure IX-2.

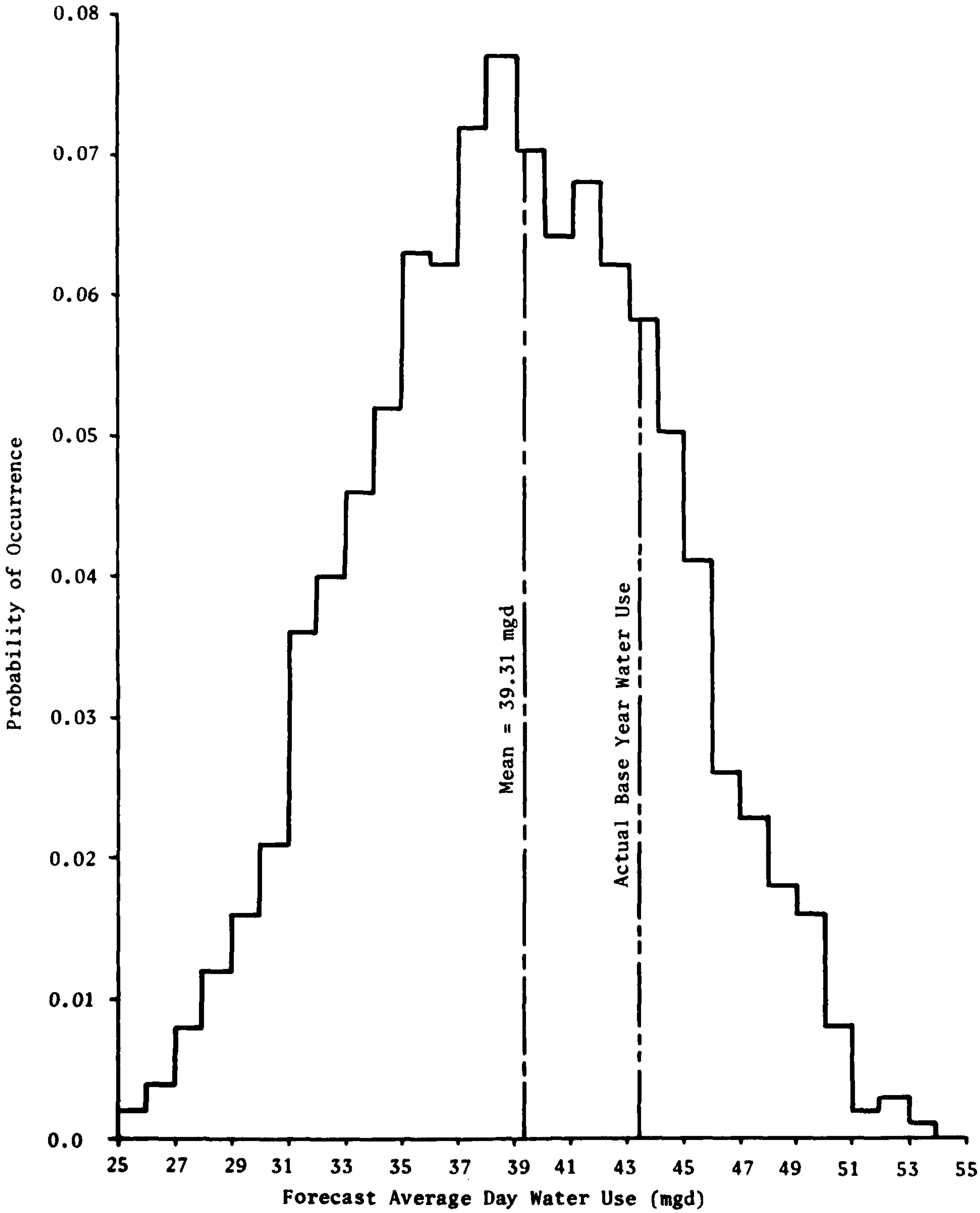

Figure IX-1. Forecast Water Use Histogram, 2000

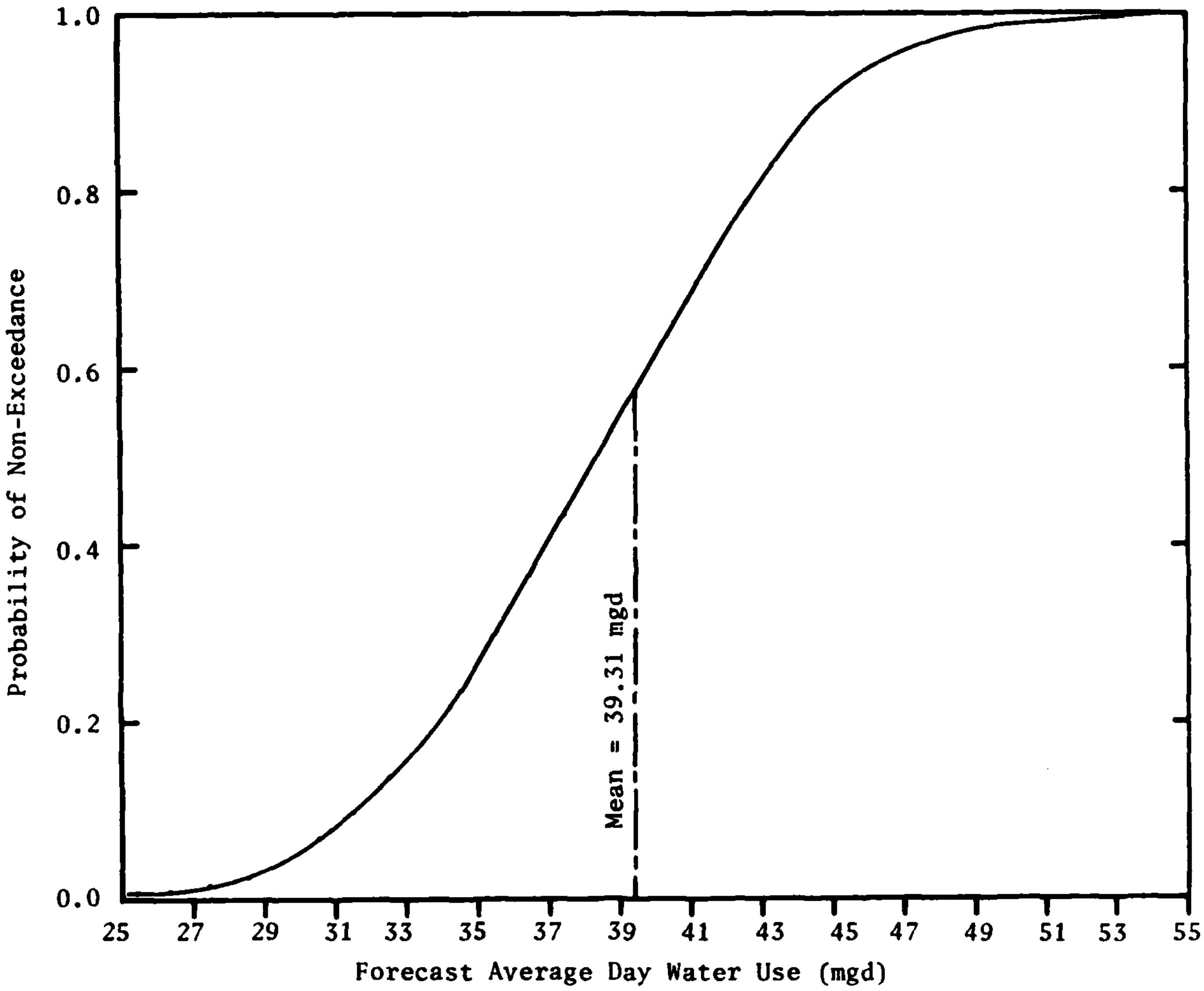

Figure IX-2. Cumulative Probability Distribution of Forecast Water Use, 2000

Analysis of Results

PROBLEMS ENCOUNTERED

In addition to those problems encountered in the Example C forecast (Section VII), there are three important concerns in completing a probabilistic forecast. The first is deciding which of the factors in the sector models to choose for investigation of alternatives. The second is determining alternative values of those factors, and the third is assigning relative probabilities to the chosen alternative values. Some guidance is evident when sufficient data exist to construct a probability distribution for the factor. However there is still the problem of picking alternatives which are representative of a particular probability of occurrence. The greatest degree of subjectivity is evident where little or no information exists for either the magnitude of alternatives or the probability distribution of a variable chosen for alternatives.

Several assumptions had to be made during the interpretation of the data and the calculation of the forecast. The most important of these is that the alternative values of the water use in each sector are independent of those of all other alternatives in other sectors. This assumption simplifies calculation by defining the probability of a forecast alternative as the product of marginal probabilities of the constituent sector alternatives.

APPLICATION OF RESULTS

A probabilistic forecast has a wide range of application, especially in the design of water supply facilities. Its usefulness in this application is limited only by the degree to which all uncertain factors can be quantified and incorporated into the analysis. In the case of this example, Figure IX-2 indicates a mean forecast water use of 39.31 mgd. Conventional design practice would suggest that a water supply capable of providing exactly 39.31 mgd would be unsatisfactory, that some margin of safety should be added to provide suitable supply reliability. The results shown on Figure IX-2 indicate that, assuming all significant sources of uncertainty have been included, a reliability of 80% (supply capacity not exceeded with a probability of 80%) can be achieved by providing a capacity of 43 mgd (a safety margin of 3.69 mgd). Similarly, a reliability target of 95% can be achieved by providing 47 mgd supply capacity.

Probabilistic forecasts, in addition to providing for explicit treatment of reliability in design, permit the application of risk-benefit analysis or other techniques to determine optimal reliability targets. They also permit more accurate measurement of water supply project benefits where the benefit function is asymmetric. For example, suppose that low future water use will provide no project benefits at all (existing facilities are adequate), water use near the mean will provide moderate benefits, and high future water use will provide very large benefits. Conventional measurement techniques, which calculate benefits at the mean, may significantly underestimate true project benefits. Probabilistic methods permit the expected value of project benefits to be determined, by taking the probability-weighted average of the full range of possible future benefits.

COMPARISON WITH OTHER FORECASTS

As described in Section VII, another forecast is available for the study area. Table IX-1 contrasts that forecast for the year 2000 with the results of the probabilistic forecast. It can be seen that the alternative forecast of total water use is very close to the mean of the probabilistic forecast. The alternative forecast for each sector, furthermore, lies well within the range of probabilistic forecasts, although differences from the means vary from negligible (public/unaccounted) to significant (residential).

Table IX-1. Comparison With Other Forecast, (mgd)

Sector	Other Study	Probabilistic Forecast	
		Mean	Range
Residential	16.09	13.89	8.08 -- 19.73
Manufacturing Remainder C/I	9.94	10.86	9.77 -- 11.95
Military	8.24	8.77	4.49 -- 13.05
Unaccounted	5.78	5.79	3.16 -- 9.17
Total	40.05	39.31	25.5 -- 53.9

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